Precipitation from individual storms in this region is rarely heavy, amounts as much as 1 inch per hour occurring on the average not more than once per year at each station, while amounts of 2 inches or more in 24 hours do not occur more frequently.

In Figure 3 is shown graphically the general distribution of annual precipitation over the Great Lakes region, based upon the 50-year averages of all the stations.

In general, precipitation increases southward from the upper to the lower Lakes, though there are well-marked exceptions, notably near the shores of southern Lake Huron, on both the Michigan and Canadian sides, where the annual averages are nearly 5 inches less than further east or west and but little greater than those found in portions of the northern Superior drainage. On the other hand, in the Georgian Bay region of Ontario there is an area with distinctly heavier amounts, in some instances averaging nearly 10 inches above the figures for northern Michigan on the opposite side of Lake Huron.

Another area of apparently light precipitation is found along the north shore of Lake Ontario and at a few points on the south shore, particularly near the lake level. Elsewhere over the drainage area the annual precipitation, as stated previously, increases gradually from north to south, ranging from about 25 inches along the northern watershed of Lake Superior to nearly 40 inches over that of southern Lake Erie.

Precipitation over the Lake region is rather evenly distributed through the year, with a tendency toward heavier amounts during the warmer portions. This is particularly noticeable over the western districts, where the distribution more nearly resembles the Great Plains and upper Mississippi Valley type, *viz:* Moderately heavy precipitation in summer and usually light in winter. Here the warm-season precipitation ranges from 60 to 70 per cent of the yearly total. Farther east, however, there is some tendency toward heavier precipitation during the colder period of the year. This is most pronounced east of Lake Huron where, in the Georgian Bay district, nearly 60 per cent of the precipitation occurs in the six months October to March, inclusive.

The percentages of precipitation for the two periods, April to September and October to March, inclusive, are shown on Figure 4.

Over the lake surfaces.—With regard to the amount of water falling on the lake surfaces as compared with the adjacent land areas, it is of course impossible to make definite statements, though there is strong evidence that the catch in gages where exposures are comparable with the actual lake surface is less near the lake than farther away from it.

In northern Lake Michigan, a station has been maintained at St. James on the extreme northern part of Beaver Island, located about 25 miles off the eastern shore, and approximately 50 miles from the western shore, for a period of about 20 years. Comparing identical years with Mackinaw City, on the adjacent mainland, it is found that St. James receives only 94 per cent as great precipitation as Mackinaw. Similarly, near the western shore of the same lake, on Plum Island, off the extreme northern end of the peninsula which separates Green Bay from the lake, a station has been in operation for a number of years. Comparing identical years with two stations on the mainland some 25 miles equi-distant northwest and southwest of Plum Island, it appears to receive only 92 and 96 per cent, respectively, of the amounts for the two shore stations, or 94 per cent of an average for the two stations, the same as in the preceding case.

On the southern side of Lake Superior the Keweenaw Peninsula just northeastward nearly 50 miles into the lake, at the extreme northern part of which is the station of Eagle Harbor, Mich. The gage at this station is located only a few feet above the lake on the immediate shore and exposed to the full force of the lake winds. At Calumet, about half way between the base and the extreme northern point of the peninsula, but located inland about 4 miles, there is a station also with ground exposure for the gage, but at an elevation more than 600 feet higher than at Eagle Harbor, and probably protected from the full force of the winds by the general forest cover. Comparing similar years of record, Eagle Harbor receives only 80 per cent as much precipitation as Calumet. On the other hand, comparing Eagle Harbor with Houghton, Mich., a regular Weather Bureau station at the base of the peninsula and about 10 miles inland, with the rain gage exposed on the roof of a building 57 feet high, but probably not as fully exposed to the wind as at Eagle Harbor, the catch is only 14 per cent greater than at Eagle Harbor. Houghton has 10 per cent less precipitation than Calumet, due doubtless to the difference in wind effect on the catch of the two gages, and also to the higher elevation of Calumet.

Considering the comparatively small differences in the average annual precipitation in the cases cited above, and the well-known fact that the winds are usually higher over the lake surfaces than on the adjacent shores, also that increased wind velocity materially lessens the catch, it may be expected that gages located away from the mainland, on islands or peninsulas, will register less precipitation than would be measured on the shore; but this, it is thought, would in no important particular indicate a lessened actual fall over the lake surface as a whole, as compared with the amounts received at shore stations near the lake level, but simply a lessened catch.

IMPORTANT VARIATIONS OF PRECIPITATION IN THE LAST 50 YEARS

The record of nonperiodic variations.—Aside from giving the above general survey of precipitation, the purpose of this investigation was to ascertain what important changes have occurred in the amount or distribution of precipitation over the Great Lakes drainage area during the 50-year period 1875 to 1924.

Viewing the data from nearly 100 different points, on the yearly totals at each station in the separate lake basins, and averages for each basin as a whole, both by figures and diagrams, it becomes apparent at once that the outstanding features are the heavy precipitation during the first 10 years of the period over the greater part of the area, the persistent and important decreases during the following few years, the rather steady, but, on the whole, diminishing annual totals for the period about 1896 to 1916, and the marked decreases in practically all the region since 1916, including 1925.

The heavy precipitation occurring in the early years is not peculiar to the lake region alone, as is shown by figure 2.

This gives the average precipitation for five-year periods from 1872 to 1924, inclusive, over the eastern two-thirds of the United States, based upon the records of 60 well distributed observation points in that area.

For a period of about 10 years, 1875 to 1885, the precipitation for this area averaged nearly 45 inches, whereas during the remainder of the period the averages are mainly only slightly more than 40 inches or even less.

In the tables and diagrams showing the precipitation over the combined lake areas, as well as on the separate lakes, similar conditions appear and the same holds good for the individual long-record stations, particularly in the Superior, Michigan, and Huron basins, where, with two or three exceptions, all stations show much heavier precipitation during the early years.

Dividing the adopted 50 years of record into two periods of 25 years each, 1875 to 1899, and 1900 to 1924, inclusive, and charting the differences between the two sets of averages for all the stations (see fig. 5), it becomes evident at once that a large deficiency has accumulated during the later period over the greater part of the basin, the area of important losses embracing practically all the Michigan, Huron, and Erie basins, where the average loss per year ranges from 3 to 8 inches, the area of greatest loss, slightly more than 8 inches, occurring in the northern portion of the lower Michigan peninsula. Losses of from 2 to 4 inches per year occurred over much of the Superior basin and locally in that of Ontario. There was apparently a slight increase in precipitation during portions of the second 25 years at a few points north of Lake Superior and locally in some of the other basins, particularly on the Canadian side. On the whole, however, there is indisputable evidence of a large deficit in precipitation over the Lake region in recent years.[1]

Considering the drainage areas of the four lakes, Superior, Huron, Michigan, and Erie only, some unusually dry years occurred, even in the earlier part of the period. In 1888 the average precipitation for this entire area was only 29.6 inches, and the preceding and following years were nearly as dry. The driest of the 50 years was 1895, when the average was 27.6 inches, and 1894 was likewise dry.[2] The year 1910 with 27.8 inches was the second driest of the period, but both the preceding and following years had amounts above normal. Continuing the record to 1925, that year had the least precipitation since 1875, with an average of 27 inches only.

Examining the dry periods by groups of three years, one preceding and one following the driest year, 1887–89 had an average of 30 inches, 1894–96 had 29.8 inches, and 1909–11, 31.7 inches. However, the past three years, 1923–25, had but 29.2, this last group being the driest in the 51 years, and the six preceding years also had amounts less than normal.

The longest period with precipitation continuously below normal over practically all portions of the basin, but not so low as in some single years, embraces the last eight years of the period, 1917 to 1924, inclusive, in which only one year, 1921, approached closely the normal. Including 1925, the period is increased to nine years. The average deficiency for the entire watershed during this period was more than 2 inches per year, and ranged up to 6 inches or more in some portions. (See fig. 6.)

The possibility of periodic variations.—No other weather element varies so greatly as precipitation, nor has its upper limit been ascertained. Like other weather elements, however, despite its wide variation, precipitation always tends to return to the amount common to the area considered. The Great Lakes region is as free from violent fluctuations of precipitation as any other part of the country; nevertheless, there are material variations in the yearly amounts, and it is probably within the limits of good judgment to state that periods of marked excess of precipitation will usually be followed by changes to the opposite condition, and that these swings may at times be effective over 5 to 25 or more years. Probably the best guide to future conditions is knowledge secured by a careful survey of the past.

A record of 50 years' annual precipitation is far too short to establish any conclusion as to the length of these periodic swings, but the 88 years of record at St. Paul, Minn., referred to previously, may again be examined. In the five-year groups in Figure 2 there is evidence of well-marked periods of heavy and light rainfall recurring at intervals of 20 to 30 years. The more important crests center at 1847, 1868 and again in 1902, while important depressions occur between, the latest continuing at the present time. It is therefore within the bounds of precedent to expect in that locality, a return to normal or possibly to above normal within the next few years.

As regards the effect of such a return on lake levels, however, the evidence indicates that owing to the characteristic lag in response of lake levels to precipitation, the lake stages would probably go lower unless the increase of precipitation above normal were very marked.

Attention is invited also to the record of 100 years' precipitation observations at Marietta, Ohio, and the 96 years' at Rochester, N. Y., shown on the same diagram with St. Paul. The five-year averages at these places show long periods of precipitation with general trends above or below normal, though there is little evidence of any pronounced recurrence of wet and dry periods at anything like uniform intervals. At Marietta, however, the trend is upward at the present time, the precipitation for the past 10 years approaching closely the wettest periods of the record. At Rochester the past five years have been among the driest of record, though not so dry as the five-year periods centering at 1837, 1887, and 1907. Here the trend is at present downward, and as the five-year averages of precipitation have been below normal for 20 years or more, it is perhaps an allowable conclusion that in this locality precipitation will soon return to normal or above.

No matter how we may view the question of the distribution of precipitation in the Great Lakes region during the past 50 years, there can be but one conclusion: that there has been a marked falling off in the amount of precipitation received in recent years, as compared with the amounts 40 to 50 years ago. There is, however, apparently no cause to suspect human agencies as being responsible for any important part of this lessening. Nor has any other area of the earth's surface suffered within recent times a permanent important change of climate, a fact indicated by the rate of forest growth, which appears to have been not greatly variable for hundreds or even thousands of years, and by the agricultural products which have in many cases remained unchanged since earliest times. It is therefore safe to predict that fluctuations in the amounts of precipitation over this region will occur in the future as in the past, and we shall again experience the generous distribution received during the earlier years of rainfall measurement in this region.

[1] This is also true for the United States as a whole.—Editor.

[2] The diminishing precipitation in the lake region during the years 1894–95 was common to the eastern and central portions of the United States, the drought years seemingly progressing from the Mississippi Valley eastward.—Editor.

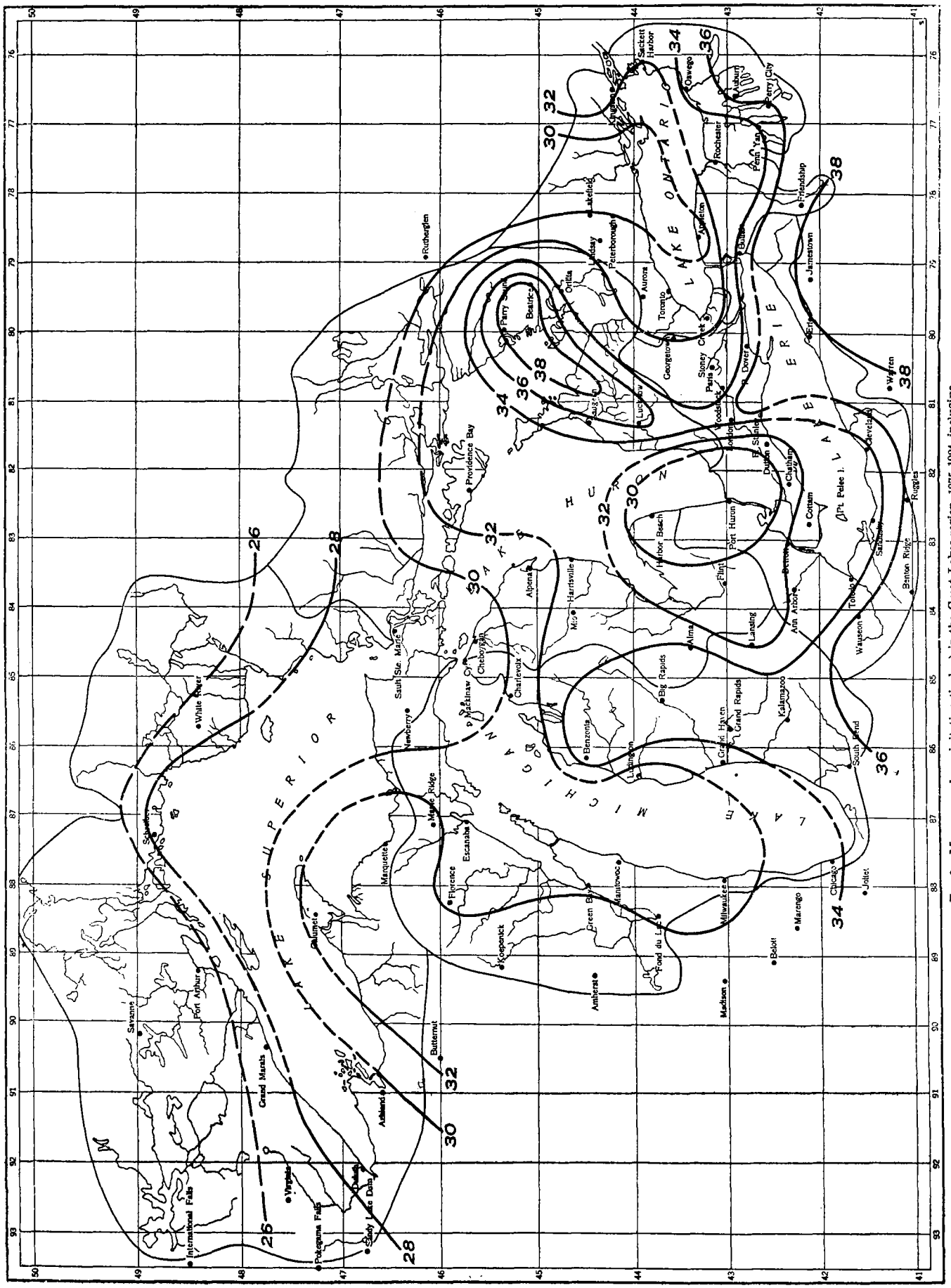

FIG. 3.—Mean annual precipitation (inches) in the Great Lakes region, 1875-1924, inclusive

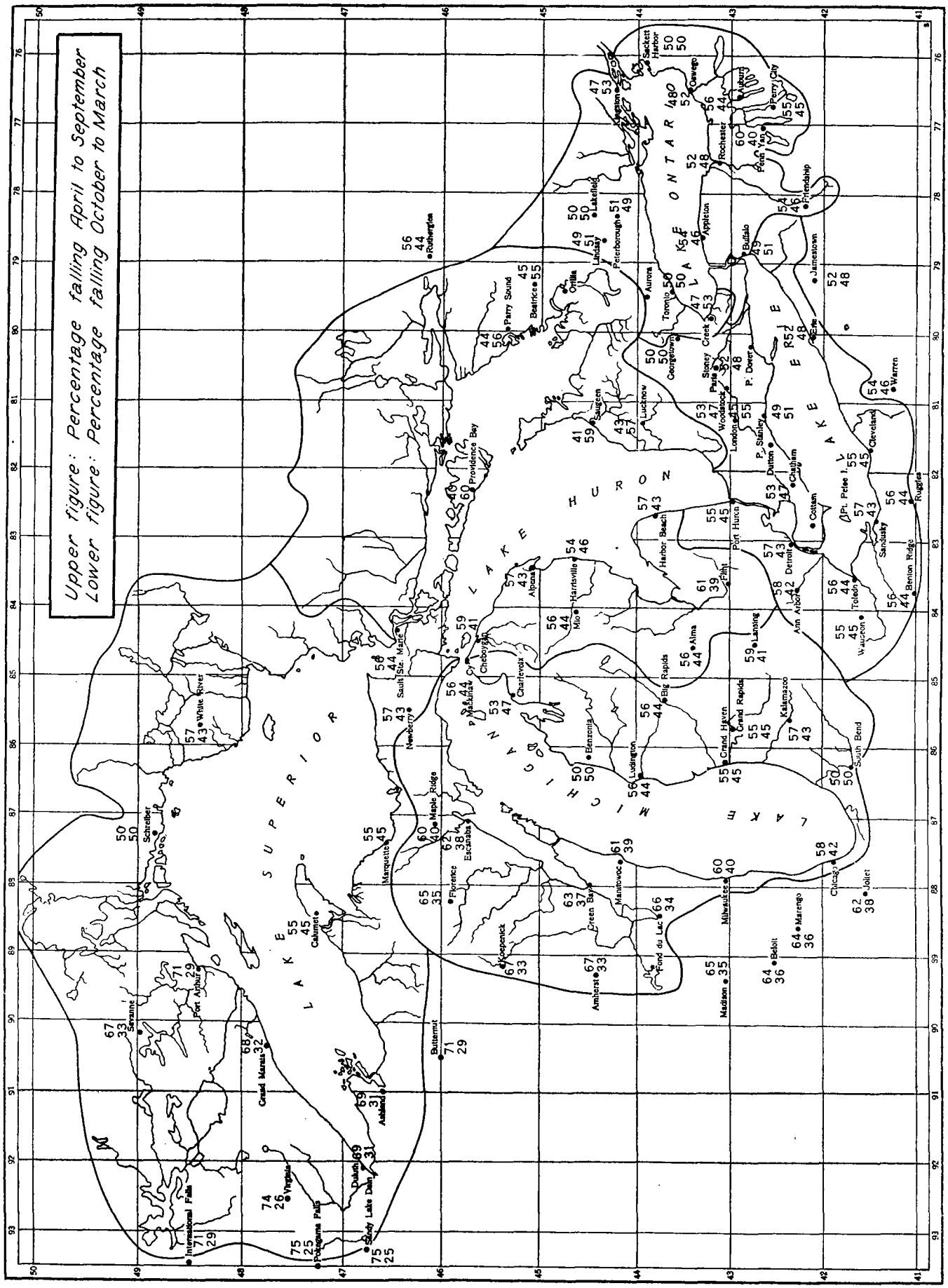

FIG. 4.—Average percentages of precipitation occurring in the two half-years, Great Lakes region

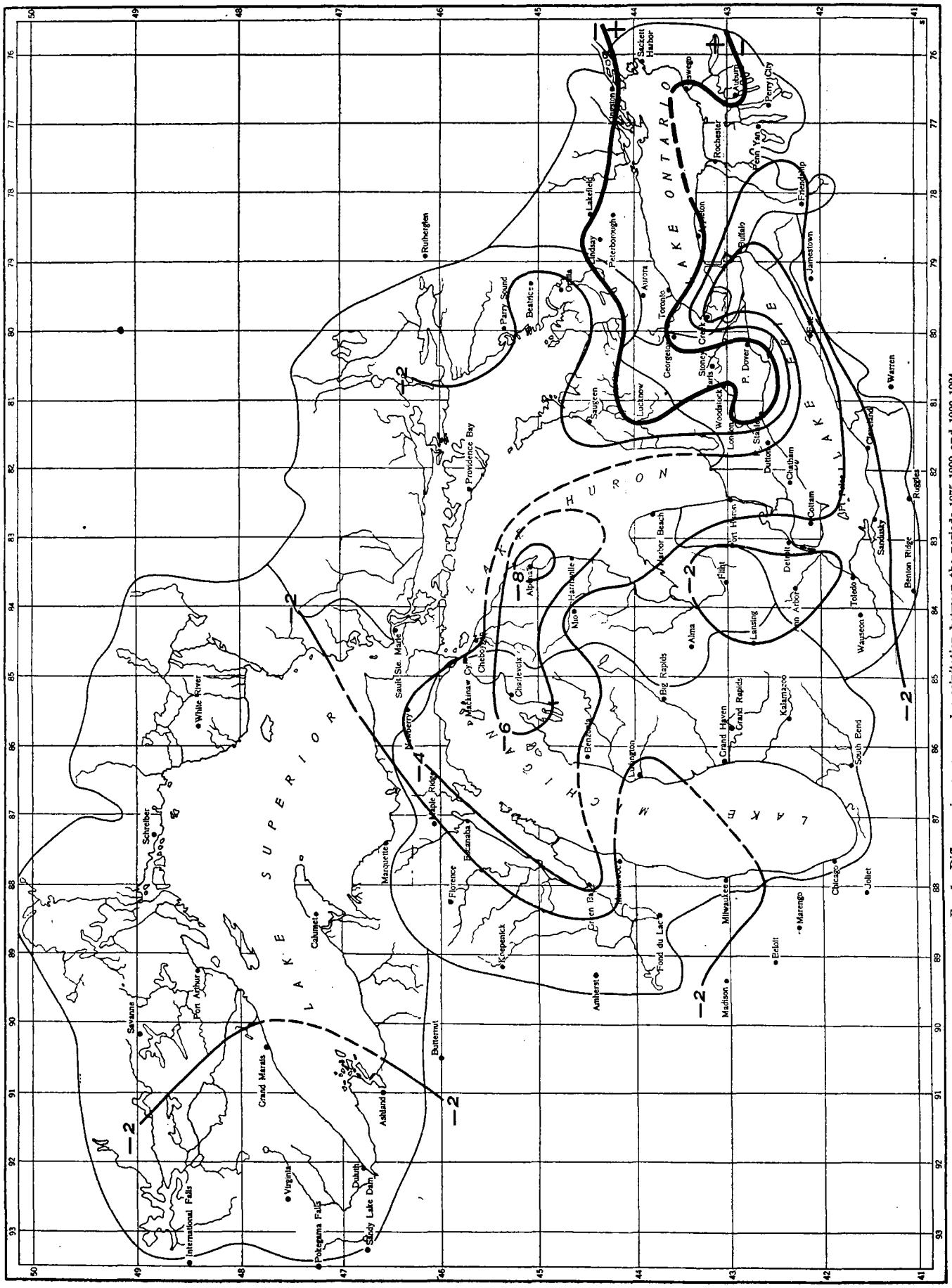

FIG. 5.—Difference in mean annual precipitation between the periods 1875–1899 and 1900–1924

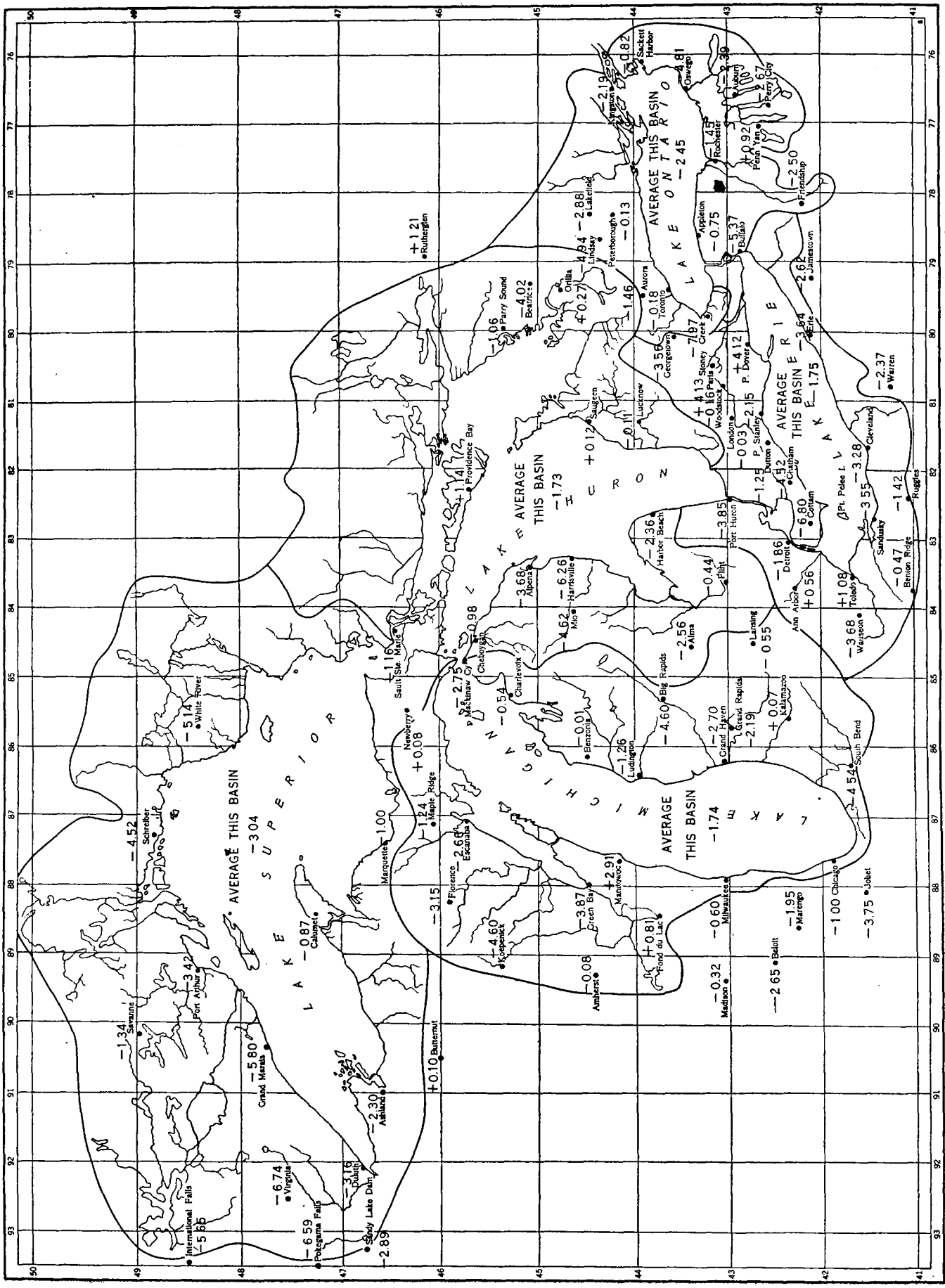

FIG. 6.—Mean annual departures of precipitation over the Great Lakes region for the 8-year period 1917–1924, inclusive, from the 50-year normal

RECORDED CHANGES IN THE LEVELS OF THE GREAT LAKES AND THEIR RELATION TO EVAPORATION AND PRECIPITATION.

Evaporation as a possible cause of reduction in lake levels.—Of all the lakes making up the chain from Superior to Ontario the first named has been affected least by the human activities usually assigned as being to some extent responsible for changes in climate.

The greater part of its drainage area lies north of the lake and in a region still largely covered by the original forest. Hence, deforestation as a factor in reducing precipitation and its resultant run-off, into this lake at least, must be eliminated as a factor.

Increase in the rate of evaporation has been assigned by some as a possible partial cause for the reduction in the lake levels, this change, it is assumed, being brought about by destruction of the forests, the possible increase in wind velocity thereby, the drainage of swamps and changes in the character of the ground cover.

As stated above none of these have been extensively operative in the Lake Superior district, but the level of that lake has apparently fallen more rapidly than the others. In advance of the fuller discussion of lake levels in the section on "Lake levels and precipitation," following, it may be stated that for the period 1875 to 1916 the range in the Lake Superior level was but 1.7 feet, while that of Huron–Michigan for the same period was 3.6 feet, slightly more than twice as great. Since 1916, including 1925, the fall in Superior has been about 2 feet, while for Huron–Michigan it has been 3.1, only one-third greater. This *proportionately* greater decline in the level of Lake Superior can not logically be ascribed to increased evaporation from its surface since the factors usually assigned as influencing evaporation have not materially changed in that area.

Evaporation is to a very large extent dependent upon the difference between the vapor tension due to the temperature of the water surface and that of the air directly in contact with it. If the difference be great, evaporation will be rapid, while it will decrease as the two values of vapor tension approach each other.

Hayford (*2*) says in discussing run-off and evaporation:

> The run-off and the evaporation in question have not been measured directly. From sources of information which are in part external to this investigation, it is estimated that during the months June–October of each year the run-off into Lake Erie from the surrounding land-drainage area is such as to produce a rise from 0.004 to 0.040 foot per day in the mean lake surface, with only a small percentage of days in which the rise is more than 0.020 foot. For Lake Michigan–Huron the run-off expressed in the same terms is even more constant.
>
> So, too, from external evidence, it is estimated that on either lake during the season June to October the evaporation produces a fall in the mean lake surface varying from but little more than 0.000 foot on some days to 0.021 foot on days of extremely rapid evaporation. * * *

The above estimate of the maximum evaporation loss is supported by the few direct observations made by the United States engineers at Milwaukee (*3*) in 1862–64 as given in Table No. 1 below. That table also includes the monthly totals of evaporation as recorded at the three evaporation stations maintained by the Weather Bureau in the general region of the Great Lakes, but not, however, close to any one of them. These stations are located at Centerville, Minn., Columbus, Ohio, and Ithaca, N. Y., and the record is for the months May–September, both inclusive, 1919–1925.

TABLE 1.—*Monthly evaporation in inches and hundredths at certain stations*

Station and year	May	June	July	Aug.	Sept.	Total
Milwaukee, Wis.:						
1862	4.90	5.54	6.49	5.76	4.13	26.82
1863	3.75	5.41	5.18	4.73	4.00	23.07
1864	8.36	7.53	7.45	4.78	2.00	30.12
Average	5.67	6.16	6.37	5.09	3.38	26.67
Centerville, Minn.:						
1919				6.62	4.51	
1920	6.07	5.71	7.17	6.07	4.64	29.66
1921	5.61	7.29	10.68	6.19	4.37	34.14
1922	5.75	7.56	6.20	5.87	4.23	29.61
1923	7.01	6.56	7.06	5.33	4.39	30.35
1924	6.38	5.74	6.14	7.25	3.36	28.87
1925	[1] [7.26]	7.67	5.92	8.37	5.69	[1] [34.91]
Average	6.35	6.76	7.20	6.53	4.46	31.26
Columbus, Ohio (State University):						
1919	3.45	6.11	[2] 6.84	5.40	4.25	26.05
1920	4.87	5.12	6.02	3.58	3.63	23.22
1921	4.89	6.42	6.68	5.85	3.40	27.24
1922	4.69	5.69	6.12	4.91	4.02	25.43
1923	4.56	5.26	5.68	4.34	3.42	23.26
1924	3.17	4.05	5.78	5.76	3.38	22.14
1925	[3] 5.83	7.12	5.77	4.94	4.32	27.98
Average	4.49	5.68	6.13	4.97	3.77	25.05
Ithaca, N. Y.:						
1919	3.70	5.11	5.60	4.00	3.74	22.15
1920	4.93	4.78	5.02	4.45	4.07	23.25
1921	4.58	5.90	5.58	5.33	4.10	25.49
1922	4.74	4.95	5.81	5.11	7.05	27.66
1923	4.24	5.06	5.75	4.85	2.37	22.27
1924	2.65	4.53	5.04	4.28	2.31	18.81
1925	3.42	6.05	5.14	4.12	2.43	21.16
Average	4.04	5.20	5.42	4.59	3.72	22.97

[1] Figures in square brackets are interpolated.
[2] Record for Wooster, Ohio, which should compare favorably with Columbus.
[3] Partly estimated.

The air temperatures and presumably the water temperatures also, during the great majority of the months comprised in the record, were above normal, especially in 1921, 1922, and 1923; evaporation was at a maximum in 1921 except at the Ithaca station, where the maximum was deferred until 1922. Considered as a whole the temperature was favorable to rapid evaporation during the first four years and the wind movement was not adverse to it, but during the last three years temperature conditions were not particularly favorable for any increase in evaporation.

The difficulty of applying the results of the pan observations at the three stations to large water areas such as the Great Lakes is recognized.[3]

Lake levels and precipitation.—In view of the importance of the commercial interests around the shores of the Great Lakes, the vast amount of freight transported on their surfaces, the constant trend toward the use of vessels with greater tonnage as a matter of economy in transportation, and the depth limitations of harbors and connecting channels, any changes, actual or prospective, which indicate a lowering of the levels of these waterways are viewed with much concern. A discussion of the distribution of precipitation over their drainage areas would be incomplete without some comparison of this with their stages.

Through the courtesy of the United States Lake Survey Office, Detroit, Mich., transcripts of the monthly and annual levels of the several lakes from about 1860 to

[3] An extensive and interesting discussion of the possibilities of evaporation from the Great Lakes is now in course of preparation by Mr. John R. Freeman, consulting engineer, Providence, R. I., in which the problem is approached by several different methods, but mainly by measurements of differences between the inflow into the lakes and the discharge therefrom, and by consideration of the temperature, wind and other conditions over their surfaces, based upon many years of observation.

1924 have been secured and diagrams showing graphically these annual levels are presented with those of precipitation, for each of the lakes and for certain combinations of these for the 50-year period 1875 to 1924. (Figs. 7, 8, 9.)

On account of the extensive area of the region under discussion, the various sizes of the lakes and of their respective watersheds, the different amounts of precipitation over their drainage areas and the large dependence of the levels of Lakes Huron, Michigan and the lower chain upon the discharge from Lake Superior, a close correlation of the levels of the individual lakes with the precipitation over their respective basins is impossible save for Lake Superior.

Lake Superior.—This lake, having a mean elevation above sea level of about 602.2 feet, or 21.3 feet above that of Lakes Huron and Michigan, is influenced in no particular by the conditions existing in the lower lakes. Its stages should therefore respond directly to the precipitation over its drainage area. It has a seasonal range in level of about 1 foot, being usually highest in the late summer and early fall, averaging 602.78 feet in September, and lowest in late winter and early spring, averaging 601.75 in March.

For the period, 1860 to 1924, inclusive, the highest yearly average was 603.06 in 1876, except in 1916 when partly by artificial means [1] the level was raised to 603.10 feet, and the lowest 601.42 in 1924, though it was only a trifle higher in 1879, 1892 and 1911, the extreme range by years being but 1.64 feet.

In general the levels of this lake respond to the precipitation over the drainage area, though usually the maximum effect of one year's precipitation is not reached until the following year unless it is excessive or deficient early in the season.

The highest yearly average ever reached under normal conditions, that is prior to the installation of the regulatory works in 1916, is 603.06 feet in 1876, although the precipitation for that and the preceding year, as shown by the few stations then in operation, does not appear to have been materially above the normal. However, the lake was nearly as high for several years preceding, and the excess of precipitation in 1876 was promptly effective in continuing the rise.

Immediately following this high stage there was a marked fall in the lake level for three consecutive years, during which the precipitation, though still above normal, diminished somewhat for two of the years, but not in the volume apparently necessary to produce such a large change in the lake level, while the last year of the three had apparently the heaviest precipitation of the 50 years under consideraton. This was without effect in staying the downward trend of the lake level for that year, though its influence is shown in the prompt and important rise in the two following years. The failure of the heavy precipitation in 1879 to stay the fall in lake level for that year was doubtless in a measure due to its occurrence mainly late in the season. Also it is possible the interpolated values of precipitation, assigning heavy falls to the entire drainage area, as indicated by the few records available at that time, may have been in error. Furthermore, there is some evidence of error in the measurements of lake levels, as shown by unusual changes in some of the months, and to the fact that portions of these records also were interpolated. Another significant fact is that the higher the lake level the greater the opportunity for a rapid run-off through the enlargement of the usual discharge channels. The levels will therefore be lowered much more rapidly when at flood than at lower stages.

There are occasional instances when the full extent of the rise or fall, but particularly of the rise, is coincident with the year of increased or decreased precipitation. These are well illustrated in the rises associated with the moderately heavy precipitation of 1893, 1894, 1899 and 1916. In the latter case, however, compensating works at the outlet of Lake Superior had, as already pointed out, permanently raised the level of that lake by about 1 foot. These works must have become operative to some extent prior to 1916, as indicated by a rise of 1.7 feet in the level between 1911 and 1916, without any large excess of precipitation, while the completion of the works in 1916 is doubtless responsible for the sharp rise in that year, although there was a material increase in the precipitation also.

During the following year, however, there was a striking deficiency in precipitation, and the lake level fell off rapidly, apparently from no other cause than lack of precipitation over the watershed.

Beginning with 1917, the annual precipitation in this basin has been constantly below normal, and except for slight interruptions, the lake level has continued to fall, till in 1924 it was at the lowest stage of record, though as stated previously the stage was only 0.01 foot higher in 1879. The past year has shown a continued deficiency in precipitation and the average level for 1925, 601.10 feet, is the lowest since 1860. It is clear that but for the controlling works the present actual level of Lake Superior would be nearly a foot lower, presumably all due to a lack of precipitation, unless the canals and locks leading to the lower lakes have augmented the discharge, which appears improbable since in all operations tending to improve navigation in the links connecting these lakes it has been the aim to so place excavated material that while the channel is deepened the actual outflow shall not be increased.

Examining the records of precipitation over the watershed since about 1885, when the number of reporting stations became sufficient to establish reliable values of precipitation for all portions of the drainage area, it appears that a precipitation average of about 29 inches will maintain the lake level above 602.2 feet, without artificial control.

In comparing the changes in Lake Superior levels with the precipitation over its drainage area, it is remarkable how small the responses are to important variations in precipitation. This is particularly noticeable in the great extremes of precipitation in 1884 and 1885, when the annual averages differed by about 1 foot, but the increase in lake level from 1884, the year of excessive precipitation, to 1885 was only 0.3 foot, while the decrease from 1885, the year of marked deficiency, to 1886 was but 0.4 foot. This may have been due largely to the season of the year in which the bulk of the precipitation occurred. In this case the excessive precipitation of 1884 was largely toward the latter part of the season and did not become fully effective until the following year, thereby overcoming to some extent the effects of the deficiency in 1885.

[1] Letter under date May 18, 1925, from Lieut. Col. E. J. Dent, Corps of Engineers U. S. A., reports that compensating works at the outlet of Lake Superior had permanently raised the level of that lake by about 1 foot.

Lakes Huron and Michigan.—As these lakes stand at practically the same elevation (average for the 50-year period, 580.9 feet above sea level), and their drainage areas receive usually similar amounts of precipitation, conditions affecting the level of one will be reflected promptly in the other, and they may be considered as a single lake.

Like Superior, they were at high stages near the beginning of the period, the level in 1876, 582.61 feet, being within a few inches of that in 1886, 582.96 feet, the highest in the 50-year period. The levels of these lakes also fell off rapidly, as did Superior, during the three years following 1876, due to diminishing precipitation, but the fall was somewhat less rapid than was that of low stages of Lake Superior, whose drainage area during a portion of the period was likewise experiencing an important reduction in precipitation with diminishing run-off.

There was a sharp fall of slightly more than 1 foot in the levels of Lakes Huron and Michigan from 1894 to 1895, the drought years, the greatest change within 1 year for the entire 50 years, and a continued slight fall in 1896 brought the level of Lake Michigan to an elevation of 579.47 feet, 3.49 feet lower than in 1886, as quoted from the report of the Deep Waterways Commission noted above, and within 0.41 foot of the stage of 1924, 579.06 feet, the lowest of record for the 50-year period. The 1925 stage was only 578.21 or 0.85 foot lower still.

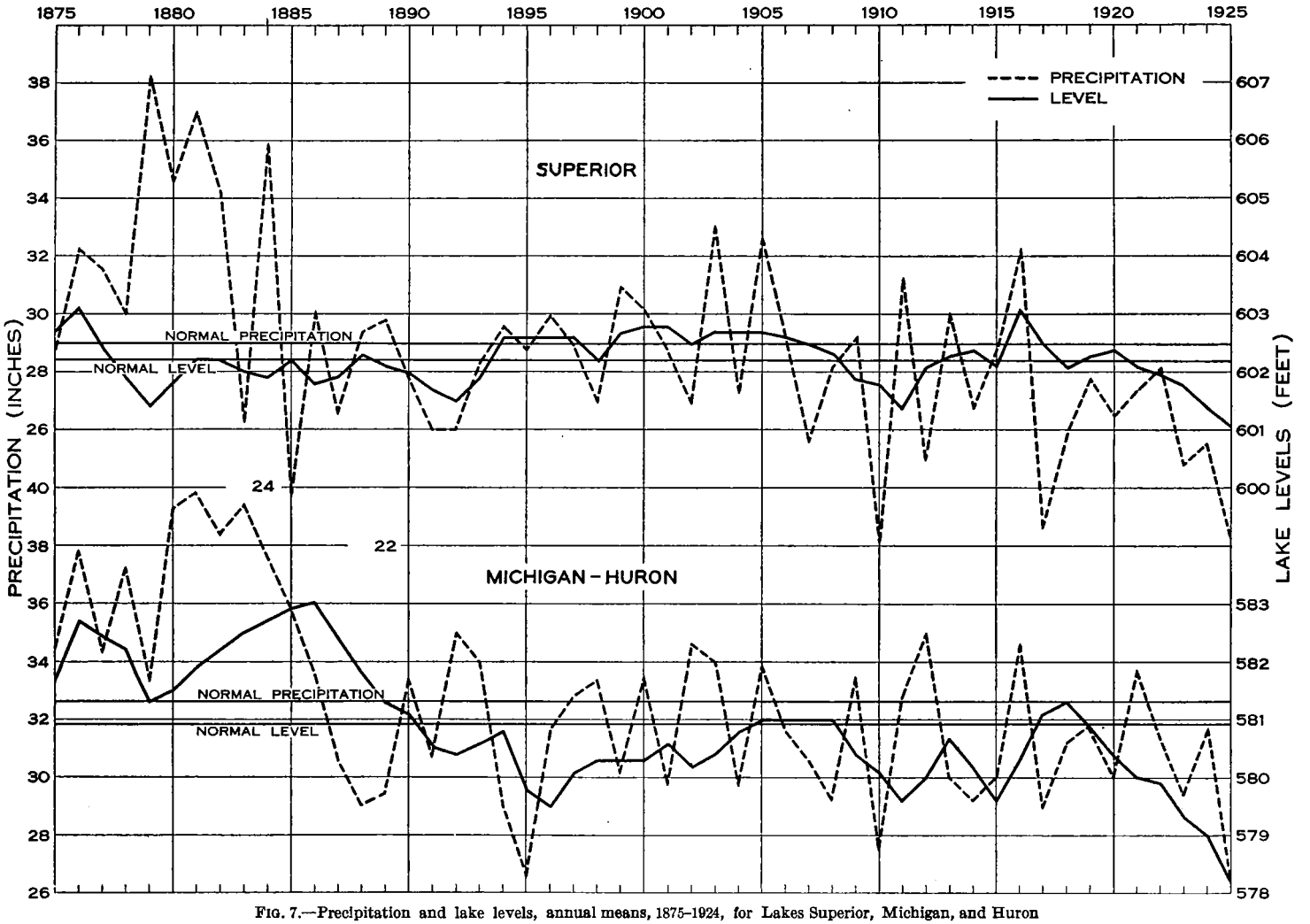

FIG. 7.—Precipitation and lake levels, annual means, 1875–1924, for Lakes Superior, Michigan, and Huron

Superior, probably on account of continued excessive discharge from that lake.

Under the influence of much the heaviest precipitation in the 50 years over the drainage basins of these lakes, from 1880 to 1885, supplemented by a nearly normal discharge from Lake Superior, they again rose steadily to a level of 582.96 feet by 1886, the highest, as previously stated, in the 50-year period and probably with one or two exceptions the highest since 1838, the year of maximum known stage, 584.34 feet.

Beginning in 1886 there was a sharp decrease in precipitation, which, with slight recoveries in 1890, 1892 and 1893, continued until 1895, inclusive, the last-named year having the least of the 50 years. The lake levels fell off during this period, the decline being augmented by the

With increasing precipitation over the basins during the 8 to 10 years following 1895, augmented by more than normal discharge from Lake Superior due to the same cause, the levels of these lakes gradually rose to slightly above normal stage of 580.90 feet, continuing steadily at 581 feet thereafter for several years.

Since 1908 there have been several sharp increases and decreases due to changing precipitation in both the Huron-Michigan and Superior basins and to increasing or decreasing discharge from Lake Superior, the lakes rising in 1918 to the highest point since 1889.

Since 1916, excepting 1921, the precipitation in the basin of these two lakes, as well as that of Lake Superior during the whole period, has been constantly below normal, the average deficiency for the 8-year period

being 1.7 inches per year, or a total of 13.6 inches for the period. During the 9 years, 1893 to 1901, inclusive, the average precipitation was slightly less in this basin than indicated above, but in this period Lake Superior levels were high and the discharge probably was materially above normal, thus offsetting the effect of decreased precipitation in the Huron-Michigan basin.

Since 1916, precipitation over the Lake Superior basin has been constantly below normal, the average yearly deficiency being 2.84 inches or a total of nearly 23 inches for the 8-year period. As a result, the water level of Superior has been greatly reduced, despite the presence of regulatory works at the Soo, and Lakes Huron and Michigan are now receiving far less discharge from Superior than usual.

The prompt rise of these lakes in 1917 and 1918 in response to the moderately heavy precipitation over their drainage areas in 1916, with nearly normal discharge from Lake Superior, shows that with an average annual precipitation of slightly more than 32 inches, the normal for the basin, and with the usual discharge from Lake Superior, these lakes will maintain their normal level.

In connection with the 1924 levels of these lakes, it is interesting to note that in their early history they showed fluctuation as great or possibly greater than any in recent years.

The report of the Board of Engineers on Deep Waterways (4), gives numerous references to the early levels of the Great Lakes, and shows that the extreme high water to which all levels concerning Lake Michigan are referred, occurred in 1838, when the elevation stood at 584.3 feet, 3.4 feet above the normal. It was nearly as high in 1858–1859.

The lowest authentic stage appears to have occurred in 1819, 577.7 feet, 6.6 feet lower than in 1838 and 0.5 foot lower than in 1925, which, with that exception, is probably the lowest of record.

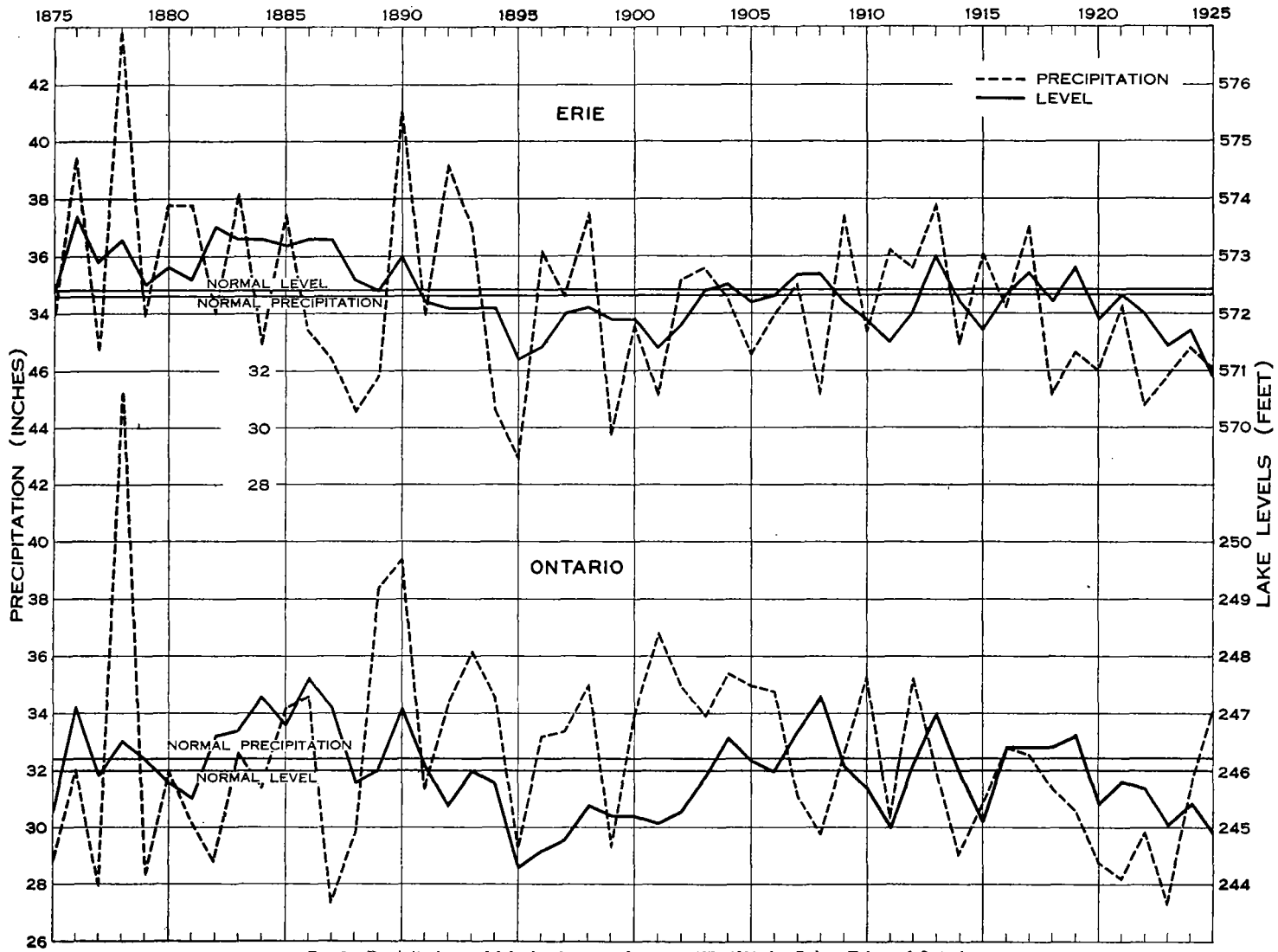

FIG. 8.—Precipitation and lake levels, annual means, 1875-1924, for Lakes Erie and Ontario

In this connection the following quotation from the report of the Board of Engineers on Deep Waterways is pertinent (4):

> The general depth of the foot of Lake Huron, 1½ miles above the head of the St. Clair River, was originally about 21 feet to 27 feet, over which were scattered numerous shoals with only 16 to 18 feet of water. A channel 2,400 feet wide and 21 feet deep at mean stage has been cut through these shoals. At the time of the last complete survey of the head of the river, in 1867, the depth across the bar over which the lake discharges into the St. Clair River was only 27 feet, and through the gorge at the head of the river the central depth was 48 feet.
>
> Investigations made during 1898 and 1899 show that a channel has been scoured through the bar 75 feet deep, and the depth in the gorge at the narrowest place increased from 48 feet to 66 feet.
>
> There is now a channel over 40 feet deep from the lake into the river, the increased outflow through which has lowered the general level of Lakes Huron and Michigan about 1 foot.

Lake Erie.—On account of the smaller area of the drainage basin, and its lower elevation, the levels of this lake are governed largely by the discharge from the higher lakes of the chain.

In general, the responses to variations in precipitation are more prompt here than in the larger lakes, though, as might be expected, they are less in degree, due to the steadying effects of the discharge from the other lakes.

Like the lakes previously discussed, Erie was at high stages near the beginning of the period, reaching a maximum in 1876 of 573.7 feet, the normal for the 50-year period being 572.4. The heavy precipitation in the early eighties over most of the Great Lakes was less pronounced in the Lake Erie basin, and the corresponding water levels did not reach the extreme high points shown by Huron-Michigan, though they continued high for a longer period.

Beginning with 1891 the Lake Erie levels fell off, due to decreasing precipitation over the whole region, and reached the lowest stage of the 50-year period, 571.2 in 1895. This, however, was not so low as in 1925, 570.9, the lowest since 1860.

With the other lakes, Ontario has been more or less below its usual level for several years, though the fall has not been so uniform or so extreme. Like Erie it rose slightly during 1924, following a considerable increase in precipitation over its basin, but fell with the other lakes in 1925, despite a continued increase in the precipitation over the drainage area, though in 1925 it did not reach the low average level of 1895 by more than half a foot.

Mathematical correlations between precipitation and lake levels.—It seems clear from an inspection of Figures 7 and 8 that an analysis of lake levels and precipitation by the method of correlation coefficients would yield interesting results. To include a reasonably comprehensive study of this character would delay publication of this paper. However, at the suggestion of the chief of bureau, we present at this time the results of the computation by Mr. E. W. Woolard and Mr. W. R. Stevens of the direct Pearsonian coefficients of correlation (with their probable errors) between the levels of the Great Lakes and the precipitation over the watersheds, using simultaneous values of the annual means of the quantities.

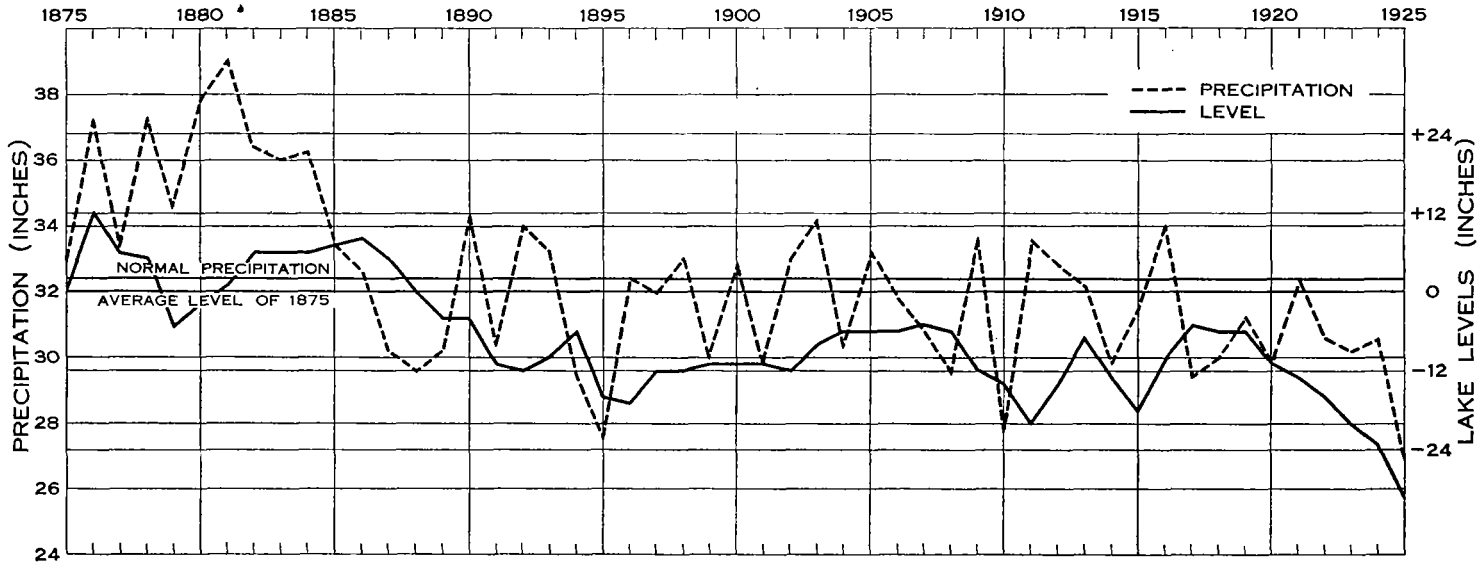

FIG. 9.—Precipitation and lake levels, 1875–1924, mean for four lakes, Superior to Erie

Precipitation continued generally less than normal for a number of years following 1895, and the lake level remained at low stages until 1902, following which there were several sharp rises and falls, also shown by the other lakes, Erie reaching comparatively high levels in 1913 and again in 1917 and 1919. Since that time the lake level has been below normal, reaching a low point of 571.4 in 1923, only slightly higher than the lowest preceding record, 571.2 in 1895, and slightly lower than in 1901 and 1911. Contrary to the case of the lakes discussed previously, Lake Erie showed a slight rise from 1923 to 1924, due evidently to increased precipitation over its watershed; but, as stated above, its stage again fell during 1925.

Lake Ontario.—This lake has an average elevation of 246 feet above sea level, or 326.4 feet lower than Lake Erie. It has generally wider fluctuations than Erie, but they are mainly similar.

Like the other lakes it was high in 1876, but reached its peak in 1886, 247.6 feet, though it was nearly as high in 1908 and again in 1913. As in the case of Erie it reached its lowest level for the 50-year period, 244.8 feet, in 1895.

Lake Superior	+0.224±0.134
Lake Erie	+.221±.134
Lake Huron-Michigan	+.505±.105

The first two coefficients, in addition to being very small, are apparently not significant (judged by their probable errors); the third apparently is significant, but, since the importance of a coefficient is measured by its square, even this coefficient is not very large. Moreover, the ordinary formula for the probable error of a correlation coefficient is not reliable for samples as small as 50.

There is, of course, a delay in the response of lake levels to precipitation. Mr. H. W. Clough has sought to bring this out by his short method of obtaining correlation coefficients, which is based on the signs of year-to-year variations. The following table shows the coefficients between precipitation and lake levels, the precipitation being compared with the lake levels of one year before, of the same year, and of one, two, and three years later:

	−1	0	+1	+2	+3
Superior	−38	+20	+55	−50	−57
Michigan-Huron	−48	−28	+52	+36	+15
Erie	−56	+57	−25	+20	−57
Ontario	−48	+40	−32	−29	+33

The sequence of the signs and the magnitude of the values clearly indicates a lag of lake levels behind precipitation, but accurate evaluation of this lag from yearly data is impossible. For Superior, the lag is apparently somewhat less than a year (about nine months) and for Michigan-Huron about a year. For the lower lakes it appears to be between two and three months. These are conclusions based on the obvious indications of the figures; there are, however, certain evident discrepancies, but discussion of these must be reserved for another paper.

It will be noted, moreover, that there is both agreement and disagreement between the values for the coefficients as computed by the Pearsonian and the short methods for the simultaneous relations of lake levels and precipitation, especially for the case of Lake Michigan-Huron. The disagreement is to a considerable extent explainable on the basis of two factors: First, in the early years of the record there was a large and persistent lag of the Michigan-Huron level behind the precipitation; second, the Pearsonian method takes account of secular trends, which in the data under review are very pronounced.

It is expected that further study of these data by the method of correlations will be carried out, using monthly or seasonal values as far as the data available permit.

SUMMARY

An attempt has been made to show graphically the relation between the average annual precipitation over the drainage area and the average combined change in lake levels resulting therefrom. (See fig. 8.)

In preparing these graphs only the four lakes, Superior to Erie, have been considered. One of the graphs shows the average annual precipitation over the four drainage areas, based on the records from all the stations used in computing the precipitation over these areas, while the other shows the average annual change in the levels of the four lakes resulting from changes in precipitation or other factors affecting their levels.

These, as may be expected, show decidedly complicated conditions, but still indicate that material variations in precipitation are effective on the lake levels for a considerably longer period than would be expected, thus making the combined changes comparatively small even when the changes in precipitation were large.

The yearly changes of the individual lakes, as previously indicated, are shown on the preceding diagrams.

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ACKNOWLEDGMENT

Much credit is due Sir Frederic Stupart, Director, Canadian Meteorological Service, Toronto, Ontario, for generous cooperation in furnishing precipitation data for the Canadian side of the Great Lakes drainage area, and to officials in charge of the Weather Bureau stations located in the area considered, who offered helpful suggestions, also to the employees of the Climatological Division for assistance in the preparation of tables, maps, and graphs.

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TABLE 2.—*Annual precipitation in the drainage area of Lake Superior, 1875–1924 (inches)*

	Duluth, Minn.	Grand Marais (near), Minn.	International Falls (near), Minn.	Pokegama Falls (near), Minn.	Sandy Lake Dam (near), Minn.	Virginia (near), Minn.	Ashland (near), Wis.	Butternut (near), Wis.	Florence (near), Wis.	Calumet, Mich.	Maple Ridge (near), Mich.	Marquette, Mich.	Newberry (near), Mich.	Sault Ste. Marie, Mich.	Port Arthur, Ont.	Savanne (near), Ont.	Schreiber (near), Ont.	White River, Ont.	Means
1875	27.03	[1] 25.34	[1] 24.62	[1] 25.68	[1] 25.95	[1] 27.84	[1] 27.22	[1] 31.33	[1] 37.36	[1] 31.90	[1] 39.49	30.22	[1] 35.15	29.66	[1] 22.16	[1] 24.15	[1] 29.10	[1] 24.56	28.82
1876	32.27	[1] 30.25	[1] 29.40	[1] 30.66	[1] 30.98	[1] 33.24	[1] 31.17	[1] 35.08	[1] 37.10	[1] 35.72	[1] 39.48	31.44	[1] 35.16	32.41	[1] 26.46	[1] 28.84	[1] 33.66	[1] 27.46	32.27
1877	34.31	[1] 32.36	[1] 31.25	[1] 32.59	[1] 32.94	[1] 35.34	[1] 31.45	[1] 34.36	[1] 31.28	[1] 34.98	[1] 33.15	27.54	[1] 29.52	27.09	[1] 28.58	[1] 30.66	[1] 34.86	[1] 26.84	31.63
1878	28.09	[1] 26.98	[1] 26.38	[1] 26.68	[1] 26.97	[1] 28.93	[1] 29.66	[1] 34.95	[1] 34.36	[1] 35.59	[1] 36.42	36.19	[1] 32.48	25.19	24.48	[1] 26.68	[1] 32.80	[1] 28.24	30.06
1879	45.28	[1] 38.10	[1] 35.91	[1] 43.02	[1] 43.47	[1] 46.64	[1] 42.77	[1] 47.54	[1] 35.50	[1] 48.40	[1] 37.60	40.75	[1] 33.56	23.09	27.42	[1] 29.89	[1] 36.78	[1] 31.72	38.19
1880	38.05	[1] 34.94	[1] 33.78	[1] 36.15	[1] 36.53	[1] 39.19	[1] 35.71	[1] 39.55	[1] 31.77	[1] 40.26	[1] 33.62	33.44	[1] 29.98	30.62	29.58	[1] 32.06	[1] 37.23	[1] 30.02	34.58
1881	37.55	[1] 33.33	[1] 31.92	[1] 35.67	[1] 36.05	[1] 38.68	[1] 38.09	[1] 43.98	[1] 40.98	[1] 44.79	[1] 48.61	42.91	[1] 43.31	24.92	26.63	[1] 29.03	[1] 36.50	[1] 32.14	36.95
1882	38.02	[1] 31.24	[1] 29.23	[1] 36.12	[1] 36.50	[1] 39.16	[1] 36.73	[1] 41.35	[1] 38.75	[1] 42.10	[1] 40.98	37.08	[1] 36.52	31.03	21.35	[1] 23.27	[1] 29.89	[1] 26.84	34.23
1883	23.20	[1] 23.42	[1] 23.18	[1] 22.04	[1] 22.27	[1] 23.90	[1] 24.68	[1] 29.17	[1] 30.20	[1] 29.70	[1] 31.56	30.50	[1] 28.58	31.20	22.75	[1] 24.80	[1] 29.75	[1] 25.00	26.44
1884	35.35	[1] 31.70	[1] 30.44	[1] 33.58	[1] 33.94	[1] 36.41	[1] 36.15	[1] 41.93	[1] 42.24	[1] 42.70	[1] 44.88	41.44	40.43	31.42	25.78	[1] 28.10	[1] 35.32	[1] 31.08	35.72
1885	19.96	[1] 19.82	[1] 19.54	[1] 18.96	[1] 19.16	[1] 20.56	[1] 21.91	[1] 26.28	[1] 29.82	[1] 26.76	[1] 31.90	28.60	30.90	27.53	18.84	[1] 20.54	[1] 25.42	[1] 22.04	23.81
1886	33.37	[1] 29.45	[1] 28.16	[1] 31.70	[1] 32.04	[1] 34.37	[1] 31.30	[1] 34.66	[1] 30.98	[1] 35.28	[1] 32.76	29.27	29.12	31.29	23.28	18.11	[1] 29.98	24.80	30.00
1887	28.56	[1] 27.69	[1] 27.16	28.18	[1] 27.42	[1] 29.42	[1] 26.96	[1] 29.94	[1] 24.25	[1] 30.48	[1] 25.70	25.62	21.72	23.16	25.48	22.80	30.22	[1] 22.69	26.52
1888	27.31	[1] 27.37	[1] 27.06	27.13	[1] 26.22	[1] 28.13	[1] 28.92	[1] 34.12	[1] 30.44	23.59	35.48	35.46	31.24	38.41	26.36	25.50	32.00	[1] 24.72	29.41
1889	32.04	[1] 29.24	28.00	25.65	27.00	30.00	30.50	30.00	[1] 28.45	31.19	28.38	30.31	30.90	35.39	24.50	26.54	[1] 35.68	33.18	29.83
1890	24.09	[1] 22.77	22.00	26.63	24.50	23.00	26.00	35.02	[1] 32.14	27.37	34.14	34.47	35.10	40.06	20.17	19.43	[1] 28.17	25.24	27.79
1891	29.47	[1] 25.99	21.00	26.00	23.00	22.50	28.36	[1] 26.04	[1] 29.08	24.74	25.33	33.78	30.27	29.57	20.52	30.59	[1] 23.64	17.07	25.94
1892	28.52	[1] 24.82	28.74	22.59	22.43	27.00	26.26	24.91	32.22	27.99	31.43	27.28	29.60	30.09	19.12	25.79	[1] 22.77	17.19	26.04
1893	23.34	[1] 23.67	29.26	26.24	23.67	26.00	28.68	31.10	32.00	25.98	32.24	35.86	33.45	39.64	23.15	22.20	27.66	28.12	28.46
1894	31.70	[1] 28.18	24.66	32.01	20.11	34.73	33.25	26.11	27.56	32.42	29.02	35.58	33.87	38.53	22.52	28.00	30.85	23.88	29.61
1895	22.30	24.62	23.93	26.53	21.70	36.10	30.36	34.89	27.29	36.82	31.11	33.04	30.59	30.55	22.47	28.71	[1] 30.20	26.08	28.74
1896	27.19	32.14	25.00	32.58	34.57	39.47	23.81	27.40	29.47	34.72	33.00	29.59	32.25	34.62	21.50	25.41	[1] 29.73	26.40	29.94
1897	30.94	32.07	25.53	28.24	34.01	30.59	30.32	35.38	27.28	28.64	26.95	30.03	29.53	36.16	24.51	26.30	[1] 26.60	17.58	28.93
1898	19.70	31.80	27.97	27.55	22.06	30.54	18.60	21.76	27.49	34.96	32.63	27.48	25.11	27.91	28.14	34.10	23.16	26.85	27.10
1899	30.62	30.00	29.00	37.23	33.46	35.39	30.12	35.74	32.63	39.28	30.87	36.43	21.82	30.68	26.53	19.44	[1] 32.73	25.79	30.99
1900	23.14	30.20	29.50	29.35	20.97	31.50	27.99	38.22	37.83	40.62	33.47	32.32	18.35	30.93	27.09	[1] 29.53	[1] 34.22	27.70	30.16
1901	26.68	25.07	26.00	29.64	21.50	30.15	31.81	28.71	32.71	31.31	45.90	37.19	18.66	27.38	22.51	[1] 24.54	[1] 30.92	27.28	28.78
1902	26.14	27.72	22.00	27.13	28.20	31.13	26.24	28.52	27.26	34.99	28.10	26.77	17.90	26.00	21.82	26.60	[1] 31.16	23.49	27.01
1903	28.01	30.00	30.00	29.77	35.36	33.90	35.69	46.68	43.27	38.51	38.00	39.84	28.21	29.04	22.11	22.87	[1] 31.92	29.46	32.92
1904	24.45	23.75	25.00	22.66	20.86	27.02	26.98	31.30	29.43	32.47	32.00	33.24	31.72	27.50	22.27	25.65	[1] 30.84	27.42	27.48
1905	35.77	32.67	35.00	37.76	36.16	42.83	33.63	41.00	32.51	35.41	32.50	28.18	26.79	25.81	26.11	26.85	[1] 32.43	25.76	32.62
1906	28.78	24.36	26.00	26.67	27.26	29.17	33.14	33.46	40.23	34.56	31.47	37.49	22.19	23.71	25.08	[1] 27.34	[1] 30.14	23.01	29.11
1907	23.87	23.60	21.00	20.97	21.91	20.59	20.82	24.98	23.02	30.68	29.46	31.62	26.50	24.42	23.89	[1] 26.04	[1] 35.36	33.31	25.67
1908	31.05	27.30	24.64	24.94	33.68	26.01	28.54	28.00	24.21	32.12	26.95	30.29	24.45	26.06	24.55	[1] 26.76	[1] 35.96	33.59	28.28
1909	33.65	27.00	29.19	24.73	29.73	32.06	34.64	29.50	35.84	33.47	31.56	29.27	29.32	24.54	20.98	[1] 22.87	[1] 30.12	27.67	29.23
1910	18.11	17.00	18.89	21.25	19.77	18.39	18.59	17.14	22.00	28.53	28.86	30.54	25.00	24.25	16.55	[1] 18.04	28.20	28.06	22.18
1911	30.30	27.60	26.61	28.55	21.96	26.31	28.89	29.69	36.78	34.64	41.55	37.22	29.35	29.08	24.93	[1] 27.17	46.09	35.37	31.23
1912	21.34	20.75	21.85	16.97	19.78	20.96	22.16	29.10	28.25	34.07	29.51	30.59	24.51	26.43	20.11	[1] 21.92	34.29	28.47	25.06
1913	28.69	27.64	27.91	32.43	27.57	29.36	29.65	35.59	31.16	30.63	29.74	30.24	30.26	30.49	26.97	[1] 29.40	40.24	20.59	29.92
1914	30.09	24.36	25.13	21.52	27.75	28.12	24.71	33.90	30.66	30.56	34.34	29.28	30.30	26.51	19.54	21.60	27.54	16.24	26.79
1915	25.77	25.60	24.00	26.24	27.73	25.56	23.87	34.45	35.05	34.77	32.93	35.24	33.73	28.43	25.43	17.20	34.29	26.25	28.70
1916	29.38	29.35	30.57	25.35	26.15	28.39	30.63	38.90	32.12	44.37	37.33	39.23	35.52	41.02	29.35	26.14	26.04	29.10	32.16
1917	23.23	24.00	15.12	15.14	20.98	18.88	25.84	28.16	19.08	29.38	27.86	27.29	26.59	23.48	14.93	20.60	23.82	24.36	22.71
1918	19.76	16.86	19.32	21.31	20.55	19.42	20.70	27.16	26.07	34.82	30.76	41.81	34.15	31.01	20.24	25.02	32.34	28.36	26.09
1919	23.77	17.99	29.55	26.17	27.25	28.62	27.30	36.76	25.15	33.81	35.51	28.54	28.53	29.39	18.14	21.09	31.32	30.49	27.74
1920	29.74	20.53	18.29	20.58	26.90	25.42	32.90	32.05	28.34	32.68	33.31	29.16	27.50	29.11	22.70	24.23	23.03	22.31	26.60
1921	25.07	22.50	20.62	20.85	25.24	21.19	25.31	38.55	32.62	26.95	32.67	31.28	32.52	31.64	22.83	27.73	25.98	24.71	27.35
1922	29.00	22.79	21.07	22.14	27.80	23.35	26.37	38.00	35.52	38.89	37.89	33.71	32.22	29.92	19.60	26.58	22.04	18.51	28.23
1923	22.29	21.77	16.93	15.75	21.83	17.80	22.13	28.84	30.25	34.09	32.33	25.35	29.15	28.38	17.59	23.18	26.02	20.95	24.73
1924	28.17	19.46	19.81	21.09	23.53	24.66	31.26	34.61	28.70	33.14	26.44	27.19	26.89	24.51	22.10	22.88	24.62	22.10	25.62
Means	28.29	26.54	25.74	26.97	27.15	29.16	28.78	32.92	31.37	33.84	33.34	32.54	29.61	29.59	23.19	25.25	30.67	26.11	28.97

[1] Interpolated.

TABLE 3.—*Annual precipitation in the drainage area of Lake Michigan, 1875–1924 (inches)*

	Amherst (near), Wis.	Beloit, Wis.	Florence, Wis.	Fond du Lac, Wis.	Green Bay, Wis.	Koepenick, Wis.	Madison, Wis.	Manitowoc, Wis.	Milwaukee, Wis.	Chicago, Ill.	Joliet (near), Ill.	Marengo, Ill.	South Bend (near), Ind.	Benzonia (near), Mich.	Big Rapids (near), Mich.	Charlevoix (near), Mich.	Escanaba, Mich.	Grand Haven, Mich.	Grand Rapids, Mich.	Kalamazoo, Mich.	Lansing, Mich.	Ludington (near), Mich.	Mackinaw City (near), Mich.	Means
1875	[1]28.46	37.44	[1]37.36	[1]25.96	[1]41.72	[1]40.06	22.80	30.26	35.56	38.06	36.52	34.68	36.20	42.90	35.00	37.63	43.54	34.41	33.67	31.00	28.44	[1]34.10	34.00	34.77
1876	[1]37.00	40.47	[1]37.10	[1]33.72	[1]46.81	[1]40.95	36.15	32.63	50.36	36.48	40.58	39.57	39.10	46.00	39.00	48.08	42.44	46.29	35.24	37.32	30.55	[1]40.84	36.00	39.68
1877	[1]30.01	40.81	[1]31.28	[1]27.36	[1]42.38	[1]33.90	27.67	28.16	46.15	41.01	34.34	34.47	44.05	35.00	34.99	33.95	34.61	36.03	31.83	47.78	37.42	[1]31.44	30.00	35.42
1878	[1]39.04	41.14	[1]34.36	[1]35.58	[1]37.26	[1]35.33	39.54	34.01	38.29	41.95	34.62	32.44	39.15	36.00	39.18	32.70	32.73	33.75	36.65	45.82	31.97	[1]30.84	29.00	36.15
1879	[1]33.12	35.70	[1]35.50	[1]30.63	[1]29.27	[1]31.23	35.21	27.22	24.93	30.71	29.62	32.61	45.00	38.00	34.95	39.56	30.76	35.48	29.91	39.21	26.72	[1]32.48	35.00	33.17
1880	[1]41.74	37.02	[1]31.77	[1]38.02	[1]31.58	[1]32.72	46.72	30.71	29.96	37.32	44.49	33.29	37.35	44.00	40.77	47.70	30.17	44.65	45.38	41.17	45.08	[1]39.24	34.00	38.47
1881	[1]48.74	46.64	[1]40.98	[1]44.40	[1]46.02	[1]46.44	52.91	37.55	39.07	44.18	45.75	47.22	45.43	43.00	47.91	44.28	48.49	47.89	43.18	41.03	34.66	[1]40.28	36.00	44.00
1882	[1]44.64	38.02	[1]38.75	[1]40.70	[1]36.02	[1]43.12	42.89	40.13	28.43	41.34	43.03	35.36	41.31	45.30	34.36	42.62	40.07	42.16	41.73	33.70	32.88	[1]38.66	37.00	39.23
1883	[1]42.62	35.68	[1]30.20	[1]38.85	[1]31.24	[1]36.48	41.13	38.12	29.47	45.86	46.51	35.91	41.62	43.42	41.42	35.60	30.02	44.84	52.14	36.33	48.36	[1]39.08	33.66	39.07
1884	[1]48.28	31.01	[1]42.24	[1]44.00	[1]38.76	[1]45.02	49.19	40.51	30.57	34.61	36.76	34.95	35.40	42.50	40.85	40.40	43.15	46.62	44.07	39.99	36.28	[1]39.49	40.32	40.22
1885	[1]38.92	37.13	[1]29.82	37.00	[1]33.44	[1]33.80	40.58	31.80	32.58	44.37	39.50	35.78	41.23	38.84	38.40	33.00	31.42	35.81	38.04	40.51	35.93	[1]33.00	28.48	36.06
1886	[1]33.73	31.92	[1]30.98	25.71	[1]33.60	[1]35.76	28.78	34.05	31.46	26.77	32.46	31.24	30.94	42.77	36.00	34.70	32.36	35.31	35.03	32.21	27.95	[1]34.46	23.39	32.24
1887	[1]35.22	31.54	[1]24.25	30.45	32.56	[1]26.54	38.89	26.47	30.46	29.13	36.16	33.24	33.52	33.06	33.00	22.96	23.01	32.75	30.98	34.48	31.10	[1]29.12	15.08	30.17
1888	[1]27.52	31.99	[1]30.44	30.82	35.47	[1]29.04	23.06	28.20	23.49	30.86	34.10	26.41	31.00	37.82	36.17	31.22	25.89	25.96	30.40	28.03	26.56	[1]28.08	26.35	29.52
1889	[1]26.11	27.97	[1]28.45	28.10	32.56	[1]29.69	20.17	28.52	31.70	34.95	32.30	24.52	35.00	35.91	28.78	28.56	26.77	24.02	27.63	28.50	23.78	[1]26.37	34.27	28.90
1890	37.57	33.88	[1]32.14	33.41	38.34	[1]33.74	36.98	32.86	30.09	32.69	32.61	36.44	37.85	31.43	37.23	29.88	30.02	32.26	26.60	35.96	31.91	[1]28.19	37.67	33.47
1891	25.68	30.70	[1]29.08	21.40	26.03	23.95	24.24	24.67	29.76	26.54	31.09	31.29	32.70	35.14	32.25	30.69	24.83	26.26	28.89	34.41	24.78	[1]27.06	32.40	28.43
1892	32.29	46.32	32.22	34.34	33.02	35.20	37.10	32.76	35.03	36.56	44.45	43.21	40.35	36.29	38.55	29.35	32.76	31.77	40.83	33.33	29.92	[1]30.06	29.63	35.45
1893	32.40	32.53	32.00	29.73	32.99	29.75	31.46	30.95	32.87	27.47	29.10	29.95	35.40	30.80	33.35	27.75	26.26	34.97	42.57	34.80	31.29	[1]29.16	25.07	31.42
1894	26.45	31.53	27.56	25.16	35.89	23.80	24.59	25.48	27.79	27.46	25.26	35.49	30.63	29.36	31.95	27.81	27.03	32.61	26.18	26.07	19.30	[1]27.46	32.43	28.14
1895	18.14	20.42	27.29	15.59	21.04	24.64	13.49	20.16	24.88	32.38	27.02	25.90	27.92	26.37	26.70	26.96	34.30	25.62	31.11	31.57	22.80	[1]23.00	27.66	25.00
1896	35.09	31.86	29.47	31.91	33.09	32.20	31.35	31.23	28.98	33.14	34.94	32.52	35.46	30.49	29.26	30.15	33.65	30.18	29.50	43.40	33.22	[1]26.84	31.77	32.16
1897	30.15	24.66	27.28	27.01	34.13	25.50	22.58	26.58	31.05	25.85	30.93	25.17	32.39	34.66	31.53	30.93	28.55	32.32	30.69	36.49	33.61	23.42	27.49	29.26
1898	28.72	40.60	27.49	25.16	29.08	30.40	31.91	25.70	32.43	33.77	44.35	38.65	38.32	38.49	36.17	37.66	30.11	36.02	34.61	28.93	32.42	24.66	32.86	32.98
1899	30.17	28.03	32.63	23.90	25.76	31.30	26.81	21.30	22.82	26.49	26.62	23.94	31.77	26.72	34.53	31.38	25.26	27.98	29.55	36.48	23.67	23.36	33.41	27.99
1900	37.63	33.97	37.83	27.45	32.76	46.55	28.78	29.34	30.10	28.65	33.08	33.68	34.55	33.96	33.44	38.57	26.86	32.33	35.30	35.29	31.62	27.30	46.46	33.72
1901	27.68	18.86	32.71	24.63	26.46	33.00	20.24	25.91	18.69	24.52	27.28	19.70	30.93	32.65	27.90	36.49	29.97	26.45	36.07	21.79	32.49	29.75	35.91	27.83
1902	32.14	39.87	27.26	29.86	27.61	27.70	31.25	32.90	28.63	37.57	56.11	39.06	41.53	33.62	34.90	24.09	22.21	34.81	39.86	38.17	38.50	27.59	31.43	33.77
1903	33.68	32.96	43.27	29.49	28.89	42.86	34.40	32.16	33.41	28.09	32.63	35.91	42.32	33.43	33.89	19.42	32.58	33.19	35.60	35.55	35.93	21.07	40.96	33.55
1904	30.22	28.66	29.43	28.51	30.63	43.00	31.25	30.29	29.86	26.14	31.36	28.04	31.47	29.69	33.13	23.98	31.70	23.97	27.93	29.44	25.90	21.45	27.43	29.28
1905	42.00	30.82	32.51	32.86	31.91	39.15	25.49	31.75	32.19	35.36	39.34	40.72	39.27	33.85	40.23	23.72	31.42	37.85	44.36	34.02	39.02	29.26	19.34	34.19
1906	39.21	29.26	40.23	33.44	37.90	39.30	32.38	30.46	30.18	30.87	32.37	28.59	35.53	26.12	39.37	17.99	31.70	29.82	28.89	31.65	29.27	33.64	19.63	31.64
1907	30.02	35.84	23.02	32.35	27.32	26.30	30.29	29.74	34.90	35.10	38.08	34.18	43.58	25.35	32.96	19.81	24.30	36.04	33.39	36.72	34.55	32.42	30.29	31.59
1908	28.73	33.08	24.21	26.70	21.91	35.34	25.67	28.52	28.32	34.83	33.13	31.77	33.06	30.81	34.31	25.73	23.93	33.35	31.17	30.26	26.63	28.98	24.13	29.33
1909	27.50	41.01	35.84	28.12	26.78	29.99	30.83	30.89	31.51	43.22	37.38	38.80	43.76	35.05	38.05	27.25	31.65	38.01	39.71	42.68	29.72	34.55	20.04	34.01
1910	22.18	23.00	22.00	20.75	29.14	24.50	24.37	25.92	21.10	26.86	24.29	22.48	33.11	29.95	24.84	22.67	27.43	25.73	23.53	30.44	25.08	26.56	24.31	25.23
1911	42.65	37.30	36.78	28.72	30.69	44.45	32.73	37.01	26.25	33.83	45.57	34.90	36.85	33.57	38.04	27.21	36.33	40.58	45.11	32.75	31.12	28.08	29.28	34.77
1912	35.12	36.01	28.25	37.53	33.32	40.99	32.32	34.38	34.59	29.67	24.10	35.29	38.23	36.02	44.03	25.58	27.32	32.43	35.20	39.45	33.50	45.67	19.31	33.40
1913	37.18	31.59	31.16	37.07	30.83	34.12	36.04	32.66	30.38	27.11	28.67	33.74	34.48	37.01	28.68	22.15	26.60	24.34	23.68	25.04	31.05	29.42	25.30	30.36
1914	32.25	32.28	30.66	32.30	38.03	26.50	28.17	30.30	32.48	28.61	26.38	31.58	31.80	41.42	27.32	25.09	28.85	35.80	29.83	30.97	30.37	34.27	24.26	30.85
1915	32.75	35.30	35.05	32.66	27.74	33.72	38.23	30.97	29.76	33.34	29.46	30.49	33.61	33.95	28.40	25.86	27.89	35.73	28.93	30.07	32.41	31.10	22.62	31.31
1916	40.27	39.19	32.12	35.07	34.19	31.43	35.33	37.38	38.05	34.05	33.38	38.73	33.86	44.20	28.08	33.59	32.31	37.75	38.58	38.02	29.48	34.98	28.60	35.16
1917	29.09	25.20	19.08	27.64	22.27	22.97	29.40	27.92	33.39	24.66	25.11	25.37	22.17	32.24	24.75	24.10	24.77	29.62	33.45	32.36	32.68	24.30	23.91	26.80
1918	37.13	30.15	26.07	28.34	31.57	28.99	27.27	36.19	28.00	33.25	31.15	28.96	34.07	36.32	29.16	29.74	27.50	30.78	31.10	37.79	31.95	28.94	26.08	30.89
1919	39.19	34.12	25.15	33.11	26.95	36.25	35.16	33.51	30.46	33.49	29.98	37.08	30.51	33.66	30.88	30.67	29.63	34.07	30.20	30.41	31.47	28.69	27.36	31.82
1920	33.69	25.61	28.34	34.68	28.76	25.83	27.16	36.36	27.86	30.21	28.50	27.36	28.83	34.96	31.64	33.05	24.72	25.13	30.01	35.14	28.44	30.73	23.68	30.03
1921	25.35	36.76	32.62	32.88	26.09	27.99	38.56	29.17	35.02	36.10	36.47	42.36	36.76	33.48	30.14	32.98	29.42	36.45	39.98	38.81	34.25	31.33	30.16	33.61
1922	36.93	30.25	35.52	30.59	34.48	28.90	32.04	34.36	25.64	31.57	28.84	25.54	28.30	40.01	34.39	32.25	33.92	32.77	35.15	29.34	28.08	34.21	32.02	31.96
1923	29.86	31.36	30.25	28.71	24.14	26.12	31.01	32.95	30.86	32.48	31.89	30.99	35.40	34.59	28.13	25.33	27.98	29.14	27.52	34.72	31.08	27.90	24.10	29.85
1924	39.07	32.56	28.70	38.68	30.63	31.41	32.38	43.04	32.30	34.96	31.62	28.92	33.45	39.38	25.16	33.34	24.59	29.45	28.53	40.32	27.77	28.84	24.99	32.18
Means	33.87	33.40	31.37	31.02	31.98	33.16	31.94	31.28	31.04	33.09	34.19	32.77	35.73	35.59	33.88	30.72	30.48	33.63	34.18	34.79	31.26	30.63	29.29	32.57

[1] Interpolated.

TABLE 4.—*Annual precipitation in the drainage area of Lake Huron, 1875–1924 (inches)*

	Alma (near), Mich.	Alpena, Mich.	Cheboygan (near), Mich.	Flint (near), Mich.	Harbor Beach (near), Mich.	Harrisville (near), Mich.	Lansing, Mich.	Mio (near), Mich.	Port Huron, Mich.	Beatrice (near), Ont.	Lucknow (near), Ont.	Orillia (near), Ont.	Parry Sound, Ont.	Providence Bay (near), Ont.	Rutherglen (near), Ont.	Saugeen, Ont.	Means
1875	[1] 34.34	37.27	[1] 33.58	[1] 28.80	[1] 30.65	[1] 37.46	28.44	[1] 40.26	29.14	39.54	30.86	33.11	39.15	41.12	[1] 27.40	33.33	34.03
1876	[1] 39.90	37.62	[1] 35.10	[1] 33.99	[1] 35.95	[1] 40.71	30.55	[1] 46.09	37.16	41.72	30.24	28.95	40.57	34.26	[1] 28.40	36.12	36.08
1877	[1] 34.88	41.00	[1] 34.26	[1] 34.40	[1] 33.42	[1] 41.05	37.42	[1] 40.27	31.61	35.26	28.64	30.86	31.59	23.56	[1] 24.32	29.71	33.27
1878	[1] 42.26	38.48	[1] 32.03	[1] 36.10	[1] 37.99	[1] 42.35	31.97	[1] 38.24	39.91	46.66	39.39	41.78	37.59	33.15	[1] 30.51	41.47	38.12
1879	[1] 31.49	39.97	[1] 31.78	[1] 27.14	[1] 30.46	[1] 38.77	26.72	[1] 42.75	27.54	43.12	35.97	34.97	35.56	30.76	[1] 27.07	35.94	33.75
1880	[1] 45.93	43.63	[1] 37.32	[1] 41.76	[1] 38.83	33.86	45.08	[1] 49.10	38.68	59.51	33.31	38.98	42.85	20.88	[1] 31.77	37.87	39.96
1881	[1] 42.79	45.61	[1] 35.58	[1] 34.98	[1] 37.25	37.42	34.66	[1] 48.31	35.27	38.08	28.06	25.27	33.26	[1] 34.60	[1] 25.77	32.97	35.62
1882	[1] 45.50	45.10	[1] 38.28	[1] 36.92	[1] 40.82	39.29	32.88	[1] 47.14	41.04	43.87	29.97	26.03	34.84	[1] 36.99	[1] 34.33	28.16	37.57
1883	[1] 48.34	35.32	[1] 33.66	[1] 42.44	[1] 35.10	36.74	48.36	[1] 38.12	36.98	54.41	36.65	39.10	43.01	[1] 36.51	[1] 33.57	37.97	39.77
1884	[1] 39.62	35.53	[1] 40.32	[1] 32.60	[1] 30.12	34.47	36.28	[1] 40.82	29.19	47.82	28.75	32.97	34.44	[1] 33.80	[1] 31.11	34.13	35.12
1885	[1] 39.32	34.71	[1] 28.48	[1] 34.82	[1] 32.86	33.58	35.93	[1] 36.39	33.81	41.96	42.16	32.15	40.40	[1] 34.21	[1] 29.48	37.50	35.48
1886	[1] 35.36	40.12	[1] 23.39	[1] 28.93	[1] 32.00	37.22	27.95	[1] 39.70	29.84	43.01	39.92	37.36	39.14	[1] 36.85	[1] 32.51	36.47	34.99
1887	33.89	37.88	[1] 15.08	[1] 27.84	30.07	35.98	31.10	32.66	24.82	36.39	41.52	28.03	34.05	[1] 31.70	[1] 23.65	33.78	31.15
1888	27.06	29.36	[1] 26.35	[1] 25.40	23.12	29.67	26.56	26.07	24.33	33.52	37.66	22.23	32.62	[1] 33.46	[1] 24.70	31.54	28.35
1889	26.50	31.32	[1] 34.27	21.84	24.64	32.69	23.78	23.42	22.22	35.77	42.66	33.88	31.20	[1] 32.64	[1] 27.76	35.11	29.98
1890	34.32	31.35	32.98	29.19	34.93	30.87	31.91	32.51	32.95	37.50	35.14	32.98	39.44	[1] 36.95	[1] 27.05	35.66	33.48
1891	34.75	31.61	32.40	25.03	28.70	40.31	24.78	28.74	33.81	40.65	39.13	33.01	38.06	[1] 33.08	[1] 31.49	37.90	33.34
1892	36.21	32.15	29.63	25.67	34.34	39.13	29.92	28.04	33.95	40.54	36.97	33.25	43.89	[1] 35.38	[1] 30.86	41.51	34.46
1893	37.00	33.35	25.07	33.44	33.78	38.54	31.29	26.52	34.80	45.58	47.73	40.14	48.03	[1] 40.34	[1] 35.23	34.73	36.60
1894	28.81	30.88	32.43	21.64	25.30	33.97	19.30	20.28	26.92	35.43	35.53	34.71	39.39	[1] 36.43	[1] 30.44	28.16	29.98
1895	24.41	21.59	27.66	21.34	24.83	28.72	22.80	23.61	26.11	35.03	33.92	29.37	38.14	[1] 29.93	[1] 28.19	32.95	28.04
1896	31.46	30.14	31.77	25.19	24.09	32.64	33.22	24.45	28.43	44.09	32.36	34.30	33.10	[1] 32.62	[1] 29.47	28.88	31.01
1897	35.42	32.59	28.84	26.09	28.62	37.95	33.61	36.70	32.10	47.74	40.90	43.66	46.28	[1] 38.34	[1] 34.64	40.41	36.49
1898	36.24	34.07	32.56	27.48	25.70	35.84	32.42	36.39	33.14	42.93	38.06	29.01	39.99	38.00	[1] 31.70	30.90	34.03
1899	26.84	29.93	29.77	29.32	24.03	32.26	23.67	30.48	25.85	41.82	39.10	38.16	43.99	41.03	[1] 31.73	32.05	32.50
1900	31.18	23.03	42.95	34.86	25.34	31.11	31.62	35.89	28.73	39.40	35.34	29.81	42.28	36.08	[1] 30.19	31.49	33.08
1901	27.57	25.23	30.34	28.28	17.46	31.71	32.49	28.40	20.36	41.92	36.40	34.81	50.30	37.41	[1] 30.94	35.96	31.85
1902	37.57	29.02	24.03	38.90	34.69	34.59	38.50	32.17	35.77	43.36	36.54	38.11	45.23	32.92	[1] 33.40	34.72	35.60
1903	38.30	31.54	22.74	36.83	28.88	36.05	35.93	34.27	32.91	40.00	37.71	34.93	38.22	39.01	[1] 28.90	35.92	34.51
1904	28.93	24.68	27.43	25.31	18.65	31.71	25.90	32.01	25.97	36.73	42.01	28.59	39.27	32.12	[1] 34.05	29.02	30.15
1905	40.20	28.14	19.34	34.96	24.70	32.73	39.02	30.46	28.97	41.95	41.87	32.41	42.99	29.82	[1] 31.45	38.39	33.59
1906	36.02	35.22	19.63	27.48	23.42	38.50	29.27	32.00	27.33	41.03	38.16	29.03	44.58	27.51	[1] 24.08	34.00	31.70
1907	33.88	22.68	30.29	29.45	18.84	31.81	34.55	32.10	27.42	39.03	34.76	23.55	37.42	26.83	23.70	26.26	29.54
1908	33.82	25.61	24.13	27.98	26.15	31.33	26.63	35.92	24.20	37.86	36.57	24.85	35.10	30.49	20.67	27.78	29.32
1909	39.32	23.75	29.81	28.59	29.54	29.79	29.72	33.82	27.82	40.63	45.14	29.31	41.58	28.89	25.42	41.78	32.81
1910	26.55	24.59	28.59	26.78	24.56	28.08	25.08	35.68	25.52	35.89	40.91	27.99	38.09	30.32	25.03	36.33	30.00
1911	35.31	27.23	34.82	27.59	30.65	32.17	31.12	43.32	26.50	34.78	36.54	20.96	31.92	26.72	23.59	31.77	30.94
1912	39.69	27.03	31.50	33.63	35.67	43.62	33.50	37.99	31.06	45.76	49.60	37.43	44.69	21.00	32.26	39.65	36.50
1913	32.17	26.50	25.07	32.38	25.72	25.31	31.05	21.14	32.61	36.31	35.22	25.78	38.69	31.45	26.22	31.98	29.85
1914	37.63	22.79	23.55	24.51	23.46	21.54	30.37	24.04	22.97	36.93	31.39	32.15	35.20	24.95	22.36	28.04	27.62
1915	30.26	27.22	26.68	28.98	28.49	26.42	32.41	28.27	25.78	34.98	36.25	24.65	30.42	19.31	27.45	33.29	28.80
1916	33.25	27.63	31.05	32.82	29.84	27.30	29.48	35.85	25.58	45.63	40.33	34.21	48.15	25.65	35.81	43.37	34.12
1917	28.13	23.79	22.14	28.60	27.65	25.84	32.68	24.55	25.32	34.62	43.05	36.15	45.91	28.64	35.29	37.90	31.27
1918	32.34	28.90	29.86	26.60	28.31	25.39	31.95	25.15	24.91	35.96	37.13	36.87	36.57	37.83	31.95	35.27	31.56
1919	34.15	26.72	33.90	27.57	23.47	22.25	31.47	28.72	24.82	46.07	42.08	33.63	40.83	35.21	30.19	29.43	31.91
1920	30.29	26.91	28.41	28.57	25.67	24.72	28.44	27.27	26.34	36.52	37.14	33.21	31.05	35.07	25.67	33.53	29.93
1921	37.92	32.94	29.51	37.59	24.66	32.39	34.25	34.11	27.65	37.43	40.51	25.47	39.48	36.22	31.50	35.83	33.59
1922	33.70	28.53	32.54	28.55	30.57	30.98	28.08	32.45	25.61	30.14	30.19	28.33	37.59	32.04	27.47	36.53	30.83
1923	32.87	26.04	23.42	29.05	25.31	25.97	31.08	28.82	25.78	31.09	32.53	30.69	33.05	23.93	30.51	29.90	28.75
1924	27.00	25.00	29.79	31.57	24.95	26.26	27.77	27.45	22.75	38.23	33.34	33.98	38.75	40.43	31.02	37.98	31.02
Means	34.61	31.03	29.68	30.20	28.68	32.98	31.26	33.18	29.25	40.28	37.11	32.02	38.96	32.53	29.24	34.43	32.84

[1] Interpolated.

TABLE 5.—*Annual precipitation in the drainage area of Lake Erie, 1875–1924 (inches)*

	Ann Arbor (near), Mich.	Detroit, Mich.	Benton Ridge (near), Ohio	Cleveland, Ohio	Rugles (near), Ohio	Sandusky, Ohio	Toledo, Ohio	Warren (near), Ohio	Wauseon, Ohio	Erie, Pa.	Buffalo, N. Y.	Jamestown (near), N. Y.	Chatham (near), Ont.	Cottam (near), Ont.	Dutton (near), Ont.	Georgetown (near), Ont.	London (near), Ont.	Paris (near), Ont.	Port Dover, Ont.	Port Stanley (near), Ont.	Woodstock, Ont.	Means
1875	30.08	35.71	39.65	36.91	33.95	[1]35.68	28.03	30.15	38.28	41.20	31.44	41.57	[1]29.20	[1]38.57	[1]27.10	34.87	32.53	34.00	30.08	29.36	34.11	33.93
1876	42.15	40.40	47.53	41.19	38.73	[1]42.77	34.55	36.45	49.58	44.65	39.26	40.40	[1]35.21	[1]43.63	[1]32.80	29.45	42.54	31.60	37.95	38.09	39.03	39.43
1877	32.61	35.23	35.80	33.13	29.95	35.52	35.17	32.88	38.56	38.96	34.48	32.40	[1]31.15	[1]38.05	[1]25.85	28.25	32.62	26.40	29.56	34.60	26.69	32.76
1878	39.89	43.39	41.20	53.51	37.00	42.91	32.67	45.09	37.24	55.23	60.24	47.15	[1]38.18	[1]46.86	[1]37.97	43.70	44.23	41.81	41.58	42.16	46.90	43.76
1879	37.22	37.17	37.75	41.52	31.35	37.71	30.27	32.52	36.69	36.25	30.47	34.88	[1]31.60	[1]40.14	[1]29.80	26.00	34.53	29.87	28.56	33.46	36.48	34.01
1880	44.25	47.68	40.80	37.38	33.30	39.44	35.72	31.19	41.00	40.94	39.26	36.40	[1]38.74	[1]51.49	[1]31.29	24.60	39.23	33.34	33.44	38.60	35.22	37.78
1881	39.93	45.44	42.25	34.96	32.70	46.31	45.91	39.65	48.06	37.62	35.95	37.40	[1]35.14	[1]49.18	[1]29.54	23.60	35.75	33.34	31.15	32.52	36.72	37.77
1882	36.21	30.32	35.65	39.98	30.85	42.53	33.03	34.41	33.56	46.37	33.82	41.25	[1]28.00	29.21	[1]28.26	27.38	35.27	29.67	31.07	32.64	33.80	33.97
1883	33.27	32.57	43.80	41.13	36.85	41.89	34.24	38.49	41.59	44.81	38.07	43.71	32.46	32.41	35.79	33.06	45.94	24.29	38.89	36.27	40.72	38.11
1884	29.18	28.17	36.80	33.26	24.35	33.64	28.43	33.73	32.91	45.47	37.07	48.97	28.42	31.24	32.56	32.60	39.85	29.09	21.48	27.02	38.51	32.99
1885	35.14	28.24	39.89	39.93	35.65	34.23	33.19	33.21	36.00	52.13	52.36	46.32	33.88	37.93	32.05	36.86	40.62	36.21	30.19	35.43	38.07	37.50
1886	28.39	26.71	30.35	27.34	32.20	31.00	32.70	30.63	30.38	37.49	44.85	36.90	29.89	34.22	33.74	35.01	39.89	34.11	38.91	37.91	30.62	33.49
1887	28.63	28.97	32.85	35.36	31.45	29.85	32.01	38.71	34.14	45.14	31.55	38.23	32.64	37.41	30.48	29.07	30.32	28.43	25.66	29.63	30.19	32.42
1888	27.23	29.02	36.95	32.57	34.61	26.45	25.86	36.57	28.49	31.94	33.87	39.13	29.17	32.79	25.67	24.25	31.07	27.41	32.63	30.80	26.47	40.62
1889	24.80	21.06	34.39	32.57	35.03	24.89	21.84	26.72	35.33	37.66	40.07	45.71	28.81	34.10	28.19	32.77	36.73	32.59	26.63	35.85	32.16	31.80
1890	35.35	34.99	42.75	47.82	47.09	38.60	33.64	48.59	39.29	47.05	46.55	59.49	41.04	38.97	33.60	34.30	41.04	34.01	37.78	40.15	40.81	41.09
1891	31.24	28.83	37.92	34.18	36.28	30.69	27.12	37.94	37.11	30.24	30.74	45.08	29.56	29.23	33.02	33.00	42.22	35.63	28.38	35.27	38.34	33.91
1892	29.93	37.11	42.74	36.51	39.49	43.28	36.70	40.56	52.55	41.67	45.87	47.07	38.36	37.54	30.07	30.20	45.88	38.57	32.70	38.31	37.83	39.19
1893	38.98	34.18	33.91	33.88	41.95	29.00	23.81	42.66	42.74	39.99	38.64	52.42	31.10	35.34	36.14	43.39	38.79	37.05	34.06	40.94	27.11	36.96
1894	25.64	25.74	30.70	27.73	26.97	28.09	21.34	35.74	32.04	35.16	38.92	47.66	25.92	26.67	28.38	27.61	34.45	31.10	32.58	30.54	28.05	30.53
1895	22.75	25.04	24.68	26.84	32.64	26.82	25.31	32.66	29.06	35.55	32.02	30.70	24.74	26.57	29.42	30.05	34.80	27.97	31.03	30.94	29.71	29.01
1896	30.05	36.20	37.30	36.68	42.25	31.76	33.10	42.31	46.57	37.02	37.29	48.90	37.77	37.31	31.80	30.46	34.36	32.91	33.90	36.68	25.82	36.21
1897	32.51	30.34	36.40	24.54	34.96	28.45	30.35	41.71	38.85	34.34	37.72	42.48	33.58	35.72	32.64	35.74	35.37	33.83	41.18	34.47	30.33	34.55
1898	33.00	34.34	39.76	32.54	43.03	43.17	28.10	43.63	44.93	34.07	33.50	52.72	36.67	36.98	33.86	34.41	44.45	34.94	32.05	39.50	31.35	37.48
1899	25.86	26.41	28.95	24.53	30.59	30.78	27.06	32.64	36.81	28.36	29.39	44.67	26.04	31.34	25.09	31.83	34.03	26.73	27.51	30.61	26.54	29.80
1900	28.58	31.45	36.35	25.83	37.76	31.80	29.58	33.87	39.38	32.62	35.93	45.06	33.75	33.70	32.36	30.98	33.78	33.48	37.19	36.09	26.25	33.61
1901	26.09	28.78	27.55	38.71	36.94	25.50	26.29	44.20	35.32	31.67	35.49	45.70	25.43	25.95	21.27	35.77	24.64	26.76	28.46	32.50	32.85	31.23
1902	41.55	35.53	36.47	39.89	35.37	36.83	33.31	38.79	44.85	29.79	32.91	41.97	30.57	34.85	23.54	33.26	30.93	30.54	32.79	42.59	34.27	35.27
1903	35.95	35.88	38.20	35.41	34.37	33.57	35.08	35.98	38.93	35.58	37.95	41.93	30.71	37.03	27.70	36.82	34.51	30.13	38.81	41.15	30.01	35.51
1904	28.19	28.32	36.82	34.56	41.19	31.87	27.94	40.87	36.36	34.96	35.83	49.56	25.86	31.07	23.82	36.32	40.92	37.46	36.04	35.13	32.49	34.55
1905	36.54	32.00	42.04	31.90	39.95	28.90	28.59	38.65	34.27	33.63	35.85	43.24	25.65	28.72	19.68	33.06	34.77	29.18	31.13	28.56	28.24	32.60
1906	30.92	33.67	32.64	31.62	40.28	34.83	30.27	38.40	33.29	38.42	33.63	34.43	26.72	32.16	32.69	36.61	42.16	33.21	29.32	35.58	37.31	34.03
1907	31.32	30.62	39.24	34.76	40.39	38.44	35.03	37.16	34.81	37.95	34.97	43.84	20.52	39.30	33.97	29.88	38.98	34.48	35.88	32.79	32.80	35.10
1908	31.04	28.59	32.93	27.60	34.30	26.48	35.88	41.27	32.79	26.72	34.24	34.61	20.89	32.86	24.19	33.04	35.95	31.55	29.58	28.89	31.21	31.17
1909	29.98	40.65	49.41	34.29	39.74	38.31	40.42	36.12	44.21	33.88	36.97	42.89	30.44	42.30	29.99	28.27	41.90	36.04	41.76	38.37	27.82	37.32
1910	27.08	24.98	37.88	33.65	37.40	32.48	29.13	37.05	32.46	35.76	42.43	40.38	29.30	32.72	22.11	33.11	37.32	34.54	36.33	38.42	28.68	33.49
1911	29.24	28.63	34.80	37.37	43.76	35.82	39.11	47.07	40.74	37.24	37.03	50.13	30.58	37.80	21.63	28.06	43.85	31.22	37.59	38.28	32.11	36.29
1912	29.06	29.66	35.36	35.94	36.51	31.76	31.95	45.58	30.43	42.09	33.22	44.36	31.64	35.44	26.25	32.07	48.32	38.85	40.40	37.19	32.28	35.64
1913	26.83	34.16	46.32	40.80	49.81	40.43	42.14	46.11	40.90	38.27	33.14	46.97	30.46	35.34	19.20	31.17	43.59	36.97	41.89	41.85	26.08	37.73
1914	32.28	30.56	33.62	28.11	39.54	31.41	35.10	38.76	32.60	36.28	34.38	40.48	29.72	31.04	23.57	25.71	35.46	31.53	34.98	37.19	32.39	33.08
1915	28.16	34.92	38.64	27.06	33.26	33.09	33.65	36.70	34.41	37.82	31.84	42.01	33.30	38.17	37.77	37.70	42.33	33.55	43.81	39.39	37.82	35.97
1916	35.57	32.21	34.77	25.94	32.58	27.20	30.54	36.23	32.54	35.44	33.38	43.23	31.44	30.28	34.20	32.19	35.49	35.42	40.68	43.46	33.79	34.12
1917	41.44	30.05	36.75	34.49	31.62	32.03	32.19	36.94	36.75	42.25	38.67	47.42	28.69	36.10	35.19	27.27	43.20	40.00	50.60	37.16	35.75	36.88
1918	33.23	31.19	30.62	27.65	32.30	25.12	31.78	32.73	29.80	38.11	32.21	41.29	18.59	23.98	23.15	31.78	36.24	34.10	38.21	30.87	34.16	31.29
1919	35.37	34.86	39.84	30.00	41.94	28.78	31.43	32.94	32.45	31.55	28.12	43.03	20.34	24.76	25.28	26.49	42.99	34.99	35.68	35.09	30.40	32.68
1920	34.87	30.70	37.03	29.94	35.21	28.07	35.78	31.76	36.05	30.71	30.77	31.90	24.45	26.12	25.22	27.85	36.77	35.71	[1]32.66	41.56	28.50	31.98
1921	33.04	31.46	36.88	32.78	36.20	32.29	34.03	38.30	33.54	35.92	26.71	43.33	30.66	31.37	23.50	28.51	40.85	42.55	[1]39.68	31.79	34.42	34.18
1922	26.14	28.83	38.43	26.21	31.87	26.81	34.04	33.15	31.89	29.73	29.41	36.17	23.98	24.73	29.53	25.07	37.79	38.20	33.33	29.55	33.53	30.88
1923	31.75	30.59	37.08	30.75	34.26	30.00	33.71	35.79	34.93	26.43	25.31	32.49	27.15	28.37	29.33	27.80	33.75	38.60	40.88	27.08	32.71	31.85
1924	25.23	24.39	36.82	32.98	33.78	36.24	31.46	39.01	30.50	34.20	33.37	44.60	29.59	23.95	30.97	27.78	31.27	37.98	39.90	32.06	31.51	32.74
Means	32.07	32.12	37.15	33.88	36.07	33.47	31.97	37.45	36.92	37.25	35.94	42.65	29.95	34.22	29.02	31.38	37.89	33.64	34.75	35.29	32.78	34.57

[1] Interpolated.

TABLE 6.—*Annual precipitation in the drainage area of Lake Ontario, 1875–1924 (inches)*

	Appleton (near), N. Y.	Auburn (near), N. Y.	Buffalo, N. Y.	Friendship (near), N. Y.	Oswego, N. Y.	Penn Yan (near), N. Y.	Perry City (near), N. Y.	Rochester, N.Y.	Sacketts Harbor (near), N. Y.	Aurora (near), Ont.	Kingston, Ont.	Lakefield (near), Ont.	Lindsay, Ont.	Peterboro (near), Ont.	Stoney Creek (near), Ont.	Toronto, Ont.	Means
1875	23.82	29.75	31.44	31.34	31.41	26.90	30.93	29.93	23.16	*28.10	28.48	24.37	*29.52	27.59	33.64	29.73	28.76
1876	22.59	35.79	39.26	36.14	34.20	33.81	39.32	35.82	25.72	*25.47	30.40	27.55	*31.20	27.16	36.73	32.40	32.10
1877	21.27	32.35	34.48	25.36	32.20	31.07	32.01	34.12	32.29	*22.63	30.38	25.30	*27.08	22.03	21.38	25.61	28.10
1878	40.82	48.85	60.24	39.26	55.83	41.43	49.39	48.81	38.85	*36.60	47.34	40.31	*44.51	37.64	46.16	48.49	45.28
1879	26.20	31.50	30.47	33.42	36.60	23.93	30.29	35.22	22.26	*21.34	32.95	23.21	*25.48	21.41	29.66	29.37	28.33
1880	25.38	35.41	39.26	31.94	43.19	23.87	32.79	41.80	23.95	*25.06	31.22	28.97	34.06	31.09	29.31	35.32	32.04
1881	24.26	36.45	35.95	37.20	39.25	30.44	37.88	38.24	22.78	*22.50	25.15	23.10	28.77	27.52	28.04	26.90	30.28
1882	24.17	28.50	33.82	36.17	36.13	23.46	29.62	24.73	25.37	*24.38	34.61	28.84	30.97	23.77	32.23	24.84	28.85
1883	29.19	33.55	38.07	41.21	34.49	33.77	35.44	30.50	28.33	*23.24	38.39	34.49	40.83	18.59	27.77	34.13	32.62
1884	16.71	27.52	37.07	48.97	31.47	26.73	34.17	31.17	29.12	30.54	36.82	28.70	34.92	33.84	27.68	28.55	31.50
1885	25.87	39.20	52.36	46.40	33.14	30.20	35.10	28.31	28.11	27.24	42.04	27.94	29.86	31.51	36.87	32.91	34.19
1886	20.02	48.07	44.85	36.90	35.46	31.73	32.92	36.84	29.54	28.57	41.73	27.86	33.64	32.48	38.67	35.08	34.65
1887	15.63	36.36	31.55	38.23	23.41	26.36	30.59	20.30	22.90	22.37	32.66	22.30	32.77	22.67	33.46	25.76	27.33
1888	23.40	44.39	33.87	34.04	32.79	31.09	30.97	27.76	30.81	22.76	32.71	22.38	27.10	27.10	30.18	26.28	29.85
1889	28.82	48.54	40.07	43.22	40.10	39.99	46.85	35.70	55.73	28.88	35.53	30.87	37.23	37.23	34.03	31.23	38.38
1890	34.62	47.42	46.55	52.07	40.86	44.27	53.07	43.09	32.14	31.32	34.20	27.68	32.56	32.56	40.36	37.37	39.38
1891	25.18	28.04	30.74	34.52	31.44	33.76	38.60	33.64	29.12	27.87	30.02	22.96	34.17	31.62	37.68	31.52	31.30
1892	24.07	30.30	45.87	40.04	34.81	34.09	43.30	35.02	40.71	30.13	35.00	28.75	32.60	33.00	34.49	29.50	34.48
1893	35.01	24.59	38.64	40.22	34.78	29.74	37.90	35.50	39.13	28.32	36.56	33.83	35.30	43.30	45.62	39.71	36.13
1894	30.79	39.08	38.92	48.39	36.44	36.92	42.55	35.11	33.21	33.90	29.53	23.44	31.71	32.48	32.74	29.56	34.67
1895	25.23	29.32	32.02	32.35	32.48	28.14	31.22	30.42	30.08	25.48	26.03	31.52	26.84	27.30	35.37	28.01	29.49
1896	28.41	34.59	37.29	36.34	38.32	41.79	36.62	36.84	33.01	24.92	25.78	29.55	32.74	31.50	33.54	29.10	33.15
1897	29.26	29.07	37.72	37.15	36.61	31.89	32.12	30.12	24.05	30.87	28.32	37.62	42.33	35.99	38.67	32.48	33.39
1898	29.06	44.71	33.50	42.40	40.44	31.75	37.60	37.50	25.29	32.98	31.50	36.37	37.16	33.46	34.20	30.95	34.93
1899	25.45	34.50	29.39	28.02	34.65	25.70	30.21	26.76	21.67	26.60	27.51	30.95	37.29	34.59	28.87	28.98	29.45
1900	29.09	38.15	35.93	35.49	37.17	30.48	35.77	38.12	34.40	28.00	30.84	30.33	35.98	35.71	37.74	29.59	33.92
1901	31.07	42.40	35.49	41.94	45.09	35.33	43.62	37.20	40.66	32.18	35.35	33.93	35.69	32.60	35.26	32.27	36.88
1902	32.74	39.04	32.91	45.72	37.87	29.18	40.85	29.73	34.53	26.96	30.44	34.71	43.01	37.79	32.57	31.02	34.94
1903	30.52	40.16	37.95	36.04	39.65	33.96	43.67	29.44	36.98	28.49	33.43	28.25	30.52	29.04	37.34	30.63	34.13
1904	26.77	41.59	35.83	35.74	39.51	34.37	36.68	34.56	37.51	31.97	34.61	26.89	38.13	34.30	41.19	35.69	35.33
1905	26.60	41.93	35.85	37.82	38.10	30.67	38.34	33.50	47.73	32.20	37.22	27.12	38.66	30.65	33.98	31.25	35.10
1906	27.83	42.90	33.63	40.35	36.23	30.69	39.29	29.74	34.31	35.83	32.26	30.20	40.23	38.13	35.05	30.98	34.85
1907	29.01	33.84	34.97	31.03	38.36	23.86	37.21	27.60	36.15	27.62	21.83	24.83	36.51	29.29	36.64	30.76	31.22
1908	23.27	30.05	34.24	33.58	33.93	23.11	33.37	27.49	31.11	28.58	33.37	27.04	37.32	27.44	23.24	29.50	29.79
1909	29.03	31.51	36.97	28.78	37.59	22.22	29.30	29.49	31.58	31.98	37.99	30.91	46.46	33.21	31.26	32.92	32.58
1910	31.78	40.48	42.43	33.68	36.99	30.12	35.56	35.52	29.35	29.18	33.36	34.50	56.08	31.12	30.92	33.63	35.29
1911	20.60	27.99	37.03	33.93	36.90	28.83	35.01	32.88	31.07	26.43	32.72	27.95	28.78	31.20	24.79	29.16	30.33
1912	28.12	45.19	33.22	32.94	40.60	26.85	31.41	29.45	39.45	35.69	36.83	35.61	45.38	40.06	31.23	32.53	35.28
1913	29.29	37.01	33.14	35.13	34.64	29.51	33.26	33.20	36.18	36.78	33.51	27.63	29.47	24.06	29.65	28.75	31.95
1914	24.06	38.58	34.38	34.91	29.80	30.47	39.61	29.83	25.77	27.00	25.16	24.35	23.37	24.20	24.91	27.17	28.97
1915	26.55	39.59	31.84	40.97	31.63	30.83	34.66	28.28	28.56	34.74	25.93	26.34	26.34	29.22	23.65	34.71	30.86
1916	29.39	34.21	33.38	37.36	28.33	39.39	29.27	36.14	37.68	31.77	37.42	30.47	30.48	31.95	25.76	31.99	32.81
1917	31.59	36.56	38.67	35.91	28.68	39.94	39.58	36.89	30.77	24.50	33.53	28.58	26.92	30.41	23.48	34.33	32.52
1918	27.02	32.52	32.21	36.49	31.25	27.06	35.88	29.35	30.98	24.42	33.05	36.94	31.67	36.88	22.90	34.41	31.44
1919	23.14	35.89	28.12	37.07	34.32	37.13	27.25	33.08	29.78	28.40	34.98	26.75	30.48	28.93	25.13	29.70	30.63
1920	20.55	36.21	30.77	30.03	32.31	27.35	33.83	27.69	31.36	28.50	27.49	22.45	27.76	30.77	23.56	29.92	28.78
1921	20.77	27.49	26.71	33.15	25.78	31.15	32.47	28.13	29.46	31.18	24.86	25.78	33.12	29.95	23.03	27.37	28.15
1922	25.60	38.27	29.41	31.33	33.10	36.61	37.18	33.02	33.08	26.23	27.35	19.23	23.68	26.95	26.39	29.14	29.79
1923	26.77	31.55	25.31	33.65	27.50	27.61	28.04	30.31	29.54	21.99	27.33	16.09	27.39	30.53	20.95	33.63	27.39
1924	32.90	32.53	33.37	37.03	31.33	30.04	31.47	31.59	32.58	30.88	32.81	29.17	28.75	31.48	22.01	33.89	31.3
Means	26.79	36.27	35.94	36.83	35.34	31.19	35.88	32.71	31.76	28.47	32.37	28.50	33.66	30.87	31.40	31.37	32.46

* Interpolated.

TABLE 7.—*Average annual precipitation (inches) in the drainage area of the Great Lakes, and average annual lake levels (feet above sea level), 1875–1924*

	Precipitation		Lake levels			
	Superior, Michigan, Huron, and Erie	All (5) lakes	Superior	Huron-Michigan	Erie	Ontario
1875	33.02	32.29	602.67	581.48	572.28	245.27
1876	37.16	36.30	603.06	582.61	573.70	247.10
1877	33.39	32.49	602.44	582.38	572.88	245.93
1878	37.19	38.57	601.87	582.07	573.29	246.50
1879	34.67	33.59	601.43	581.15	572.53	246.21
1880	37.69	36.73	601.76	581.27	572.77	245.83
1881	38.98	37.50	602.21	581.70	572.61	245.51
1882	36.32	35.05	602.21	582.19	573.48	246.57
1883	36.04	35.46	602.01	582.37	573.27	246.68
1884	36.19	35.39	601.90	582.47	573.34	247.30
1885	33.50	33.62	602.15	582.72	573.24	246.83
1886	32.62	32.97	601.85	582.96	573.34	247.60
1887	30.14	29.66	601.88	582.32	573.31	247.06
1888	29.55	29.60	602.28	581.71	572.61	245.82
1889	30.12	31.52	602.14	581.16	572.38	246.03
1890	34.21	35.09	602.00	581.05	573.05	247.07
1891	30.34	30.50	601.69	580.49	572.15	246.12
1892	34.08	34.15	601.51	580.38	572.14	245.38
1893	33.29	33.77	601.86	580.67	572.09	245.98
1894	29.50	30.38	602.56	580.78	572.10	245.79
1895	27.57	27.89	602.62	579.74	571.17	244.29
1896	32.50	32.61	602.59	579.47	571.39	244.62
1897	32.09	32.31	602.60	580.13	571.96	244.80
1898	33.05	33.37	602.17	580.31	572.14	245.37
1899	30.10	29.98	602.69	580.32	571.93	245.20
1900	32.74	32.94	602.77	580.28	571.94	245.25
1901	29.79	31.00	602.75	580.53	571.39	245.06
1902	32.99	33.32	602.53	580.21	571.84	245.27
1903	34.13	34.13	602.73	580.36	572.39	245.87
1904	30.46	31.29	602.71	580.86	572.54	246.64
1905	33.28	33.59	602.74	580.98	572.17	246.21
1906	31.71	32.25	602.63	581.05	572.26	246.05
1907	30.75	30.83	602.51	581.06	572.73	246.66
1908	29.58	29.62	602.27	580.99	572.69	247.29
1909	33.55	33.39	601.93	580.50	572.15	246.12
1910	27.73	29.01	601.78	580.15	571.87	245.67
1911	33.58	33.02	601.44	579.60	571.47	245.05
1912	32.84	33.26	602.09	580.07	572.02	246.14
1913	32.14	32.11	602.32	580.68	572.95	247.00
1914	29.85	29.70	602.38	580.24	572.17	246.05
1915	31.45	31.35	602.09	579.73	571.68	245.10
1916	33.98	33.78	603.10	580.35	572.29	246.36
1917	29.50	30.01	602.48	581.16	572.73	246.40
1918	30.03	30.27	602.07	581.40	572.25	246.44
1919	31.13	31.05	602.31	580.91	572.77	246.65
1920	29.74	29.58	602.38	580.56	571.91	245.40
1921	32.32	31.61	602.13	580.10	572.30	245.75
1922	30.58	30.44	602.01	579.98	572.00	245.73
1923	29.11	28.82	601.75	579.38	571.41	245.02
1924	30.58	30.71	601.42	579.06	571.68	245.43
Means	32.34	32.36	602.20	580.88	572.40	246.00

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Upper.—The third span of the Big Rock Bridge, about a mile below Franklin, Pa., floating down the Allegheny River on the ice gorge. This is perhaps the first time that a whole span of a steel bridge floated down a river on ice. The span traveled 1½ miles to a point near Venango. Two spans fell on the main-line tracks of the Pennsylvania Railroad five minutes after a street car laden with passengers had passed over the bridge. Photo March 28, 1926, by P. L. Mahaffey, Pennsylvania Railroad photographer

Lower.—The gorge near Venango, Pa., about 2½ miles below Franklin. The ice was moving toward the camera, and five minutes later had blocked the tracks. Here it was nearly 40 feet thick at times. Its movement was accompanied by terrifying sharp cracks and a grinding roar. Photo by P. L. Mahaffey, Pennsylvania Railroad photographer

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Upper.—"Icebergs" at Franklin, Pa., heaved out upon the banks of the river when the gorge broke, some of them destroying buildings. Photo by P. L. Mahaffey, Pennsylvania Railroad photographer

Lower.—Ice stranded in back yards in Elk Street, Franklin, Pa., soon after the gorge had gone out. The water fell with such rapidity that floes were left stranded upon the upper crust of the gorge, which had formed in some places 200 yards from the normal bed of the river, as here. Photo by Pittsburgh Post staff photographer